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Protection of River and Harbor Water from Municipal Wastes*

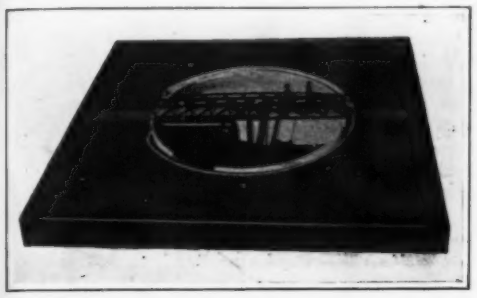
By Charles-Edward Amory Winslow, M.S.
Curator of Public Health.

THE PROBLEM OF SEWAGE DISPOSAL.

City life presents pressing and peculiar biological problems. When a large number of human beings are concentrated upon a small area the fundamental needs of individual life must be met by new means. Special measures must be adopted for getting food from a wide radius into the center where so much of it is to be consumed. The spread of epidemics which always threaten crowded communities must be guarded against; and the waste products which accompany all living processes must be removed.

This last task, the removal of the city's wastes, is one of the most difficult which confronts a modern municipality. From every large city there pours out a river of waste material which pollutes streams, harbors and foreshores, spoiling what should be the chief pleasure spots of the city and damaging property values, if it does not actually threaten human life and health. By the modern methods of sanitary science these liquid wastes can be purified and rendered harm-

*Reprinted from a Guide Leaflet published by the American Museum of Natural History.



DEEP SEDIMENTATION TANK.

A deep open tank for sedimentation of sewage. Photograph of a model in the American Museum.

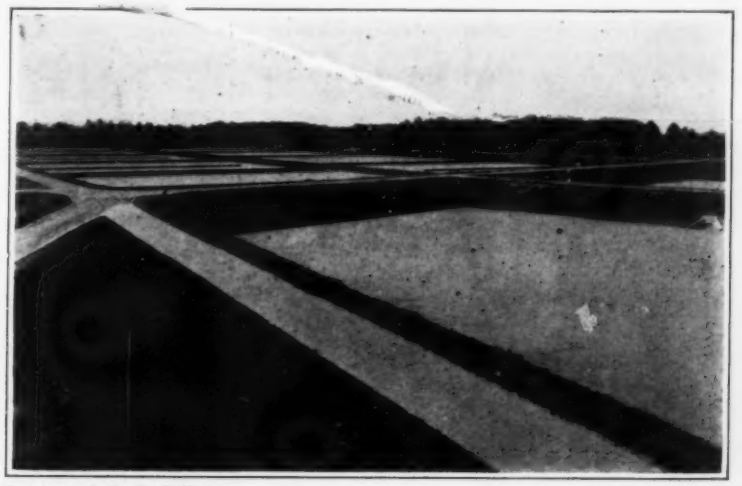
A MUNICIPAL BATHING-PLACE.

Free floating baths at various places along the waterfront are placed in close to sewer outlets, thus menacing the lives of many. Photograph of a model in the American Museum.

Courtesy of J. D. Watson.

FINE MESH REVOLVING SCREEN AT BIRMINGHAM, ENGLAND.

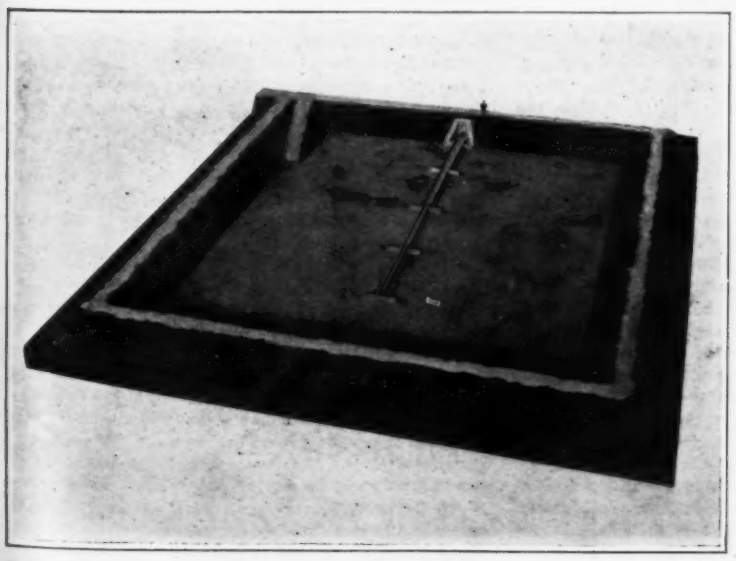
These screens constantly revolve so that a fresh surface is always ready for use.



Courtesy of G. E. Bolling.

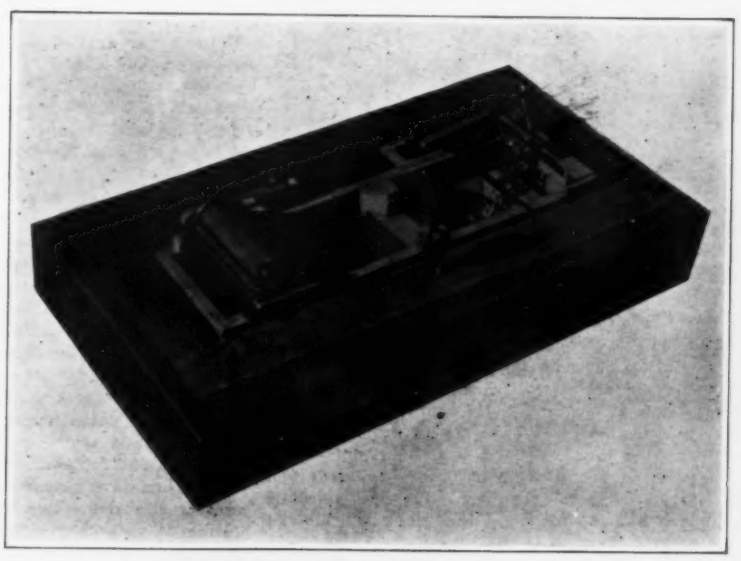
INTERMITTENT SAND FILTERS, BROCKTON, MASSACHUSETTS.

A Modern Filtration Plant.



INTERMITTENT SAND FILTER BED.

Photograph of a model in the American Museum.



FINE MESH REVOLVING SCREEN AND DETRITUS TANK FOR REMOVING SUSPENDED SOLIDS FROM SEWAGE.

Photograph of a model in the American Museum.

less and it is with such methods of protecting the purity of inland and seaboard waters that a section of the Public Health Exhibit of the American Museum now deals.

City sewage is a far less offensive substance than might be imagined. To the sight it is simply a grayish liquid with fine flecks of suspended matter in it; to the smell it is inoffensive when fresh, having only a faint musty odor. Analysis shows that the average American sewage contains less than one part in a thousand of solid matter, the rest being water. Of the solid matter half is of mineral nature, so that only a residum of perhaps four-hundredths of one per cent of organic matter requires especial treatment.

It is the vast volume of the sewage stream, however, which makes the problem such a serious one. For example, there is now discharged into New York harbor about 500,000,000 gallons of sewage a day. This amount of liquid if concentrated in one place, would fill East River under the Brooklyn Bridge for a distance of one-fifth of a mile. Even four-hundredths of one per cent of this immense mass of liquid amounts to 800 tons; and this is approximately the amount of organic matter discharged into New York harbor every day.

The organic matter in sewage, which is the principal source of embarrassment in its disposal, is made up for the most part of imperfectly oxidized unstable molecules which may undergo one or the other of two different series of changes. First, it may decompose or putrefy in the absence of oxygen, with the production of offensive gaseous compounds. Or secondly, under the influence of oxygen it may undergo another process—that of nitrification, a slow burning or combustion which converts the organic matter into nitrates or other mineral substances, without the production of foul odors and in a wholly innocuous way.

Where sewage is discharged without due precautions into the nearest water course, the first sort of change is likely to result. If the volume of the sewage in relation to the stream be small, there may be enough oxygen present to care for the organic matter. If, on the other hand, the volume of sewage exceeds the purifying capacity of the stream (which may be taken as about one part of sewage in fifty parts of water) the whole process changes; instead of self-purification, there is putrefaction. Decomposable organic matter accumulates on the bottom and the whole stream or pond is turned into a fermenting pool, the odor from which may produce a serious nuisance for considerable distances from its banks. Conditions like these now exist within the limits of Greater New York in such places as the estuaries of the Gowanus Canal and Newtown Creek.

CONDITIONS IN NEW YORK HARBOR.

New York is more fortunate than most cities in its insular position and in the large bodies of water which wash its shores. Even here, however, the present methods of disposal by the haphazard discharge of some sewers at the piers or bulkhead lines is manifestly unsatisfactory. So far as the harbor waters as a whole are concerned, it must be noted that the amount of diluting water available is much less than would at first sight appear. The hourly variations are great. Over 3,000 million cubic feet of water pass through the Narrows in a single hour at the maximum period of flood.* The total ebb at this point is 12,213 million cubic feet; but the total flood is 11,030, so that the net outflow is proportionately small. In the Hudson River the ebb is 6,910 million cubic feet and the flood 5,740 million. In the East River the figures are respectively 4,068 million and 3,968 million cubic feet, and in the Harlem River 176 million and 153 million. The result is that most of the sewage oscillates back and forth instead of passing promptly to sea.

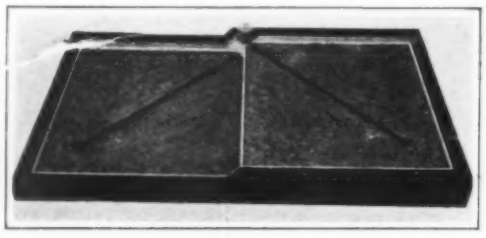
The general effect of ths pollution is manifest in the reduced oxygen content of the harbor. The East River above Hell Gate contains on the flood tide 92 per cent and on the ebb tide 80 per cent of the oxygen necessary for saturation. Below Hell Gate the values fall to 69 per cent on the flood and 60 per cent on the ebb. In the Hudson River above Spuyten Duyvil there is about 84 per cent of the oxygen necessary for saturation, on both tides; below Spuyten Duyvil the figure falls to 76 per cent on the flood and 66 per cent on the ebb. Samples taken from the eastern end of the Harlem show on the average only 43 per cent of the oxygen necessary for saturation on the flood tide and only 27 per cent on the ebb. The upper East River and the upper Hudson are in general in fair condition; the lower sections of these rivers adjoining Manhattan Island are considerable polluted; and the Harlem is grossly polluted. In the immediate vicinity of sewer outlets the conditions which exist are distinctly offensive to the senses.

Besides these conditions of local nuisance, there are real dangers to health involved in the present method of disposal of New York sewage. The wastes from a city always contain the germs of such infectious diseases as typhoid fever, and those who come in contact with water into which such wastes are discharged are liable to contract the diseases in question. More or less contact is inevitable with the waters immediately surrounding the shores and docks. Thus at the steps in Battery Park and all about the city, driftwood and other floating objects are picked out and carried by the poor to their homes. All these objects have been exposed to dangerous pollution and may carry the germs of disease. In Jamaica Bay and elsewhere near New York, clams and other shellfish are taken in the near neighborhood of public and private sewers. Some processes of cookery destroy the germs of typhoid, but others do not. The amount of disease now caused in this way is probably not large but the danger exists. The most serious of these sanitary problems is that due to bathing in the polluted waters. Free floating bathing establishments are maintained by the city at various points along the water front, often in the near vicinity of sewer outlets. It cannot be doubted that such conditions furnish excellent opportunities for infection of various sorts.

The safe and inoffensive disposal of the wastes of a large city is a difficult, but by no means an insuperable task. It involves one or more of three main processes, according to local conditions—namely, the elimination of suspended solids, the oxidation of unstable organic compounds and the destruction of pathogenic bacteria.

SCREENING OF SEWAGE.

The first problem in almost every case is the elimination of the coarser floating particles by some form of straining or screening. Sometimes this is accomplished roughly by the use of coarse bar screens with bars half an inch or an inch apart. In England and Germany finer screens of wire cloth with meshes as close as a tenth or even a twenty-fifth of an inch have been used. Such screens are frequently arranged to revolve like an endless belt, so that a fresh area



DOUBLE CONTACT BEDS FOR PURIFICATION OF SEWAGE.

Photograph of a model in the American Museum.

is constantly brought into action and the accumulated screenings are carried upward and automatically brushed off into a trough.

Where it is necessary to remove a larger portion of suspended solids that can be held back by screening, sedimentation is the next process called into play. Screening alone is sufficient for all practical purposes in some cases, so in others screening and sedimentation will produce an effluent pure enough to be discharged into adjoining waters. As a preliminary to the processes used for final purification, sedimentation almost always plays a part.

SEDIMENTATION.

The purifying action of a sedimentation tank depends on the physical factors of velocity and time. If the dimensions of the tank are such that the flow is reduced only to a rate of thirty feet per minute the heavy mineral matter—gravel, sand and the like—will be removed but the finer organic particles will not be affected. Such a small tank as this is known as a detritus tank or grit chamber, and forms a part of practically all sewage works, generally in intimate connection with the screening process.

True sedimentation of organic solids requires a velocity as low as six feet per minute or less, maintained for a period of several hours; and the tanks used for such sedimentation are usually rectangular basins of concrete or masonry with a capacity of four to twelve hours flow of sewage. In place of shallow basins of this pattern English engineers, notably at the city of Birmingham, have obtained very satisfactory results by the use of deep tanks with conical or pyramidal bottoms. The sewage enters near the bottom and as it rises and spreads out in the conical section, progressively diminishes in velocity and leaves its suspended solid matter behind, so that the effluent flows off clear at the top. These deep tanks have the added advantage that the heavy sludge can be drawn off by a valve at the bottom without emptying the liquid above. The ordinary shallow sedimentation basin will not remove more than from 50 to 65 per cent of the suspended solids, while the deep tanks at Birmingham effect a purification of 85 per cent.

Where still more complete removal of suspended solids seems to be called for, the force of gravity may be reinforced by the addition of chemicals which produce a flocculent precipitate, capable of carrying down with it the finer particles, even to some of those which exist in a state of colloidal suspension. This gives better purification but usually at a rather high cost.

THE SLUDGE PROBLEM.

In all processes of sedimentation a serious difficulty arises in connection with the disposal of the semi-solid sludge removed from the sewage and accumulated in the bottom of the basins. At the least there is produced some five to ten tons of wet sludge (containing 90 per cent of moisture) for every million gallons of sewage treated. For a community of one hundred persons (assuming 100 gallons of sewage per capita) this would mean one to two hundred pounds of wet sludge a day. With a village of one hundred persons it would be easy to deal with this semi-solid waste by burying it; but with a city of 100,000 inhabitants and 50 to 100 tons a day to dispose of, the task is far from simple. As a matter of fact this is still a problem which awaits satisfactory solution. Cities on the sea coast can carry their sewage sludge out to sea in tank steamers and dump it in deep water with reasonable success and economy. For inland communities there remain only the alternatives of burying or burning, both of which are costly and unsatisfactory. Utilization seems theoretically promising, but it has not been practically realized except with sewages like that of Bradford, England, which contain an enormous proportion of fats from industrial sources.

THE SEPTIC TANK.

There is one form of the process of sedimentation which is specially designed to minimize the sludge problem and which, to a limited extent, does achieve that end. This is the septic tank, associated particularly with the work of Cameron, but in its essential features dating far beyond the year 1895, when he gave it that picturesque name. The septic tank is indeed only a scientifically controlled and regulated cesspool, a sedimentation basin in which the suspended solids are removed by physical processes, but in which they are afterward allowed to remain so that they may be decomposed and reduced to the liquid form by the action of putrefactive bacteria.

The first septic tanks were tightly closed, in the opinion that this was essential to the desired liquefaction. It has since been found, however, that this is unnecessary. All that is essential is that the sewage, or the sludge removed from the sewage should be retained in a stagnant condition; the bacteria growing in the liquid consume oxygen much faster than it can be absorbed from the surface, and anaërobic conditions are easily maintained. In such a still pool of sewage sludge, the putrefactive bacteria effect a hydrolytic cleavage of the organic compounds and ultimately split them up into such simple forms as nitrogen, hydrogen, carbon dioxide and marsh gas.

Aside from certain minor details as to size and construction, the Cameron septic tank is simply a brick or masonry basin, covered perhaps with a wooden roof to protect it from the wind, but with no special features to distinguish it from any other tank. If in operation the sludge is removed at frequent intervals, the tank is merely a sedimentation basin. If the sludge is not removed putrefaction sets in, the liquid becomes dark colored, bubbles rise from the bottom and burst at the top and sometimes a thick crust or scum forms over the whole surface. The solids are changed first to liquid and then to gaseous form. The amount of gas evolved is large, four or five gallons from a hundred gallons of sewage, and with closed tanks it is possible to collect this gas and burn it.

The net practical result of the septic process is an appreciable reduction in the amount of stored suspended solids, due in part to the liquefying action of the bacteria and in part to consolidation of the sludge, which makes it more compact and easier to handle. The action of the tank falls far short, however, of the hopes entertained by its original promoters. Half or two-thirds of the sludge still remains to be handled, and the tank itself frequently becomes a nuisance from the evolution of odors of decomposition. Several improved types of liquefying tanks have been suggested during the last few years, of which the one designed by Imhoff for the Emscher Drainage Board of North Germany has in particular attracted wide attention. It has a tank with an upper portion through which the fresh sewage flows and a deep compartment below in which the sludge accumulates and liquefies, and it is said to effect a remarkable destruction of sludge with no obnoxious odors.

DISPOSAL OF SEWAGE BY DILUTION.

The processes so far considered are preliminary

* Data in regard to conditions in New York Harbor are quoted from the Report of the Metropolitan Sewage Commission, 1910.

processes only, which remove from the sewage a larger or smaller proportion of its burden of suspended solids, but which do not attempt ultimate purification of the organic constituents, either in solution or suspension. The final aim of sewage purification is to effect a transformation of these organic compounds into innocuous mineral substances by the action of oxygen, and this action is nitrification, practically brought about by the action of certain bacteria. When sewage is discharged in small volume into a relatively large body of water this process takes place spontaneously. The bacteria normally present in the water attack the organic matter and oxidize it and at the same time the typical sewage bacteria, finding themselves in an unfavorable environment, gradually die and disappears. Disposal by dilution, or the discharge of sewage under regulated conditions into adequate bodies of water is a recognized method of sewage purification, much used in Germany, and often with success. The discharge of too large volumes of sewage into bodies of water which could not successfully digest them has, however, frequently caused grave nuisances and dangers to health, and the undue concentration of sewage in small bays and in restricted areas near shore may produce local conditions of the same sort. Most inland cities and many seaport cities as well are therefore compelled to seek some special method of sewage treatment before their wastes can be discharged into adjacent water courses.

BROAD IRRIGATION OR SEWAGE FARMING

The most obvious alternative to the disposal of sewage in water is its distribution over the surface of suitable land; and this process of "broad irrigation" is the primitive form from which our modern modes of sewage treatment are derived. Under proper conditions the living earth readily absorbs and digests the foreign materials, by the same processes which lead to the annual disappearance of manure from heavily fertilized land; and the organic matter is not only rendered harmless, but is changed into a form in which it serves as food material for the higher plants.

Baldwin Latham, the distinguished English engineer, believed that he had discovered sewers and irrigation areas in the ancient city of Jerusalem; and in China excreta have been utilized for centuries as fertilizer for the fields. At Lausanne in Switzerland, at Milan in Italy, at Bunzlau in Prussia, irrigation was practised in the fifteenth and sixteenth centuries. The extensive development of the art dated, however, from the wave of sanitary reform which swept over England as a result of the "Report of the Health of Towns Commission" in 1844. This report marked the beginning of extensive sewerage construction in the modern sense and with sewerage, sewage disposal was urgently required. With the desire to dispose of polluting material, there grew up in these early days a parallel interest in the possible profit to be derived from crops grown on the irrigated land. The two aims are well balanced in the definition of sewage farming as "the distribution of sewage over a large surface of ordinary agricultural land, having in view a maximum growth of vegetation (consistent with due purification)."

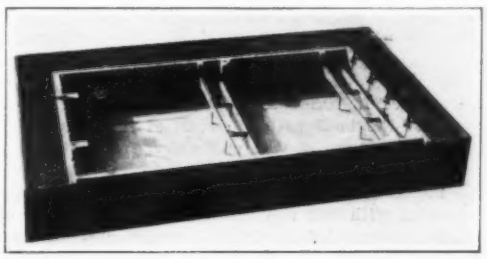
Progress in England along these lines was rapid so that over two hundred irrigation areas of various sizes were in operation by 1883. Many are still in use to-day, and on the continent, Paris and Berlin offer classic examples of this method of disposal. The Paris sewage is distributed on private land and it is not easy to form a sound judgment as to the success of the system. The Berlin farms, on the other hand, are operated by the city and offer an excellent example of sewage farming at its maximum of efficiency. The farms include 39,000 acres of excellent sandy soil, an area of over sixty square miles. Grass and cereals, potatoes and beets are cultivated, and dairies and distilleries are maintained for the utilization of the crops. Even the effluent drains are stocked with fish. The farms are operated by convict labor, and with German intelligence and German military discipline, the enterprise is not only successful as an experiment in sewage disposal, but is also economically profitable, for the crops cover all costs of operation and pay for a part of the interest charges on the land.

In general, however, the results of broad irrigation have been by no means so favorable. The process requires large areas of land. The sewage of a community of one hundred persons would need from one to two acres; and the soil must be loose and sandy in character. Where, as in many English towns, the attempt is made to treat sewage on clayey soil, disaster is almost sure to follow. The land clogs and becomes "sewage sick," a local nuisance is created and more or less unpurified sewage must be discharged into the nearest watercourse. Where local conditions and administrative efficiency are less favorable than at Berlin the economic advantage disappears. The most recent studies of the British Royal Commision indicate that cropping of irrigated land scarcely pays for itself—still less contributes toward the cost of sewage treatment. In the arid regions of the western part of the United States where every drop of water, as such, is precious and where the manurial value of sewage is reinforced by its water value, sewage farming becomes really profitable. In many parts of California and Colorado and other western States irrigation is clearly indicated as the best method of sewage treatment. Elsewhere, its application is more than problematical. The idea of converting the wastes of a city into walnut groves and fields of waving corn is an attractive one. The engineer, however, always wants to know the cost; and here, as in other modes of sewage utilization, it is poor policy to recover valuable elements that cost more to recover than their intrinsic value.

INTERMITTENT FILTRATION THROUGH SAND.

The real art of sewage disposal began only when the crude process of broad irrigation was freed from the seductive hope of agricultural gain and developed intensively and scientifically as a means for sewage disposal pure and simple. Mainly through the experiments of the Massachusetts State Board of Health at Lawrence it was shown that the essential process in sewage purification, either by dilution or broad irrigation, was an oxidation of organic compounds by the nitrifying bacteria, and that this process could be carried out much more efficiently by carefully controlling the conditions surrounding it. For a filter bed or substratum for the support of the growth of nitrifying bacteria, a fairly porous sand should be used, and the sewage should be applied in regulated intermittent doses with rests between for the supply of oxygen necessary to the process. By such means the rate of filtration can be raised from 5,000 to 10,000 gallons per acre per day (for broad irrigation) to 50,000 or 100,000 gallons. An intermittent filter of half an acre in area would therefore care for the sewage of five hundred persons, while five acres of broad irrigation area would be needed for a similar population.

The construction of intermittent filters in regions



SEPTIC TANK OR MODIFIED SEDIMENTATION BASIN

Photograph of a model in the American Museum

like the northeastern part of the United States is extremely simple. This part of the country is covered with deposits of glacial drift sand, ideal in character for sewage purification. All that is necessary is to expose and level off areas of this sand, to lay lines of underdrains a few feet below the surface to carry off the effluent, and to install devices for discharging the sewage on the surface. A bed may be dosed on one day out of three, or in smaller portions several times a day. In winter the beds are furrowed so that an ice roof forms on the top of the ridges while the sewage finds its way along the furrows between, and, although less efficient in winter than in summer, the microbes do their work at all seasons well enough for practical purposes. The effluent from an intermittent filter, properly built and carefully operated, is a clear liquid, colorless or slightly yellowish in color, with no odor or only a slightly musty one, practically free from putrescible organic matter and low in bacteria—a liquid that can be discharged with impunity into even the smallest watercourse.

The successful and economical use of the process of intermittent filtration is limited to those regions where ample areas of the right soil are easily available. In clayey or chalky regions, sand beds must be artificially constructed with material brought from a distance, and this would make the cost of the Massachusetts method almost prohibitive. In England, where the sewage problem pressed hardest for solution, sand is usually not available, and it was almost essential that further improvements should be made.

THE CONTACT BED.

Mr. W. J. Dibdin, chemist to the London County Council, was one of the first to attempt to modify the sewage filter so that it would operate at higher rates, and as a first step he naturally sought to build his beds of coarser material. In a notable series of experiments at the Barking outfall on the Thames, he found that the nitrifying bacteria could be grown on fragments of coke or stone as well as on sand, and that purification could be effected in such beds if only the sewage were held in contact with the material, instead of being allowed to stream directly through. In sand filters, frictional resistance delays the passage of the sewage, so that time is given for the purifying process. With coarser materials, however, it is necessary to regulate the flow by making the beds watertight and retaining the sewage in them until purification is completed. This was in outline the genesis of the contact bed.

Beds of this type are simply concrete or masonry basins, filled with crushed stone or coke or slag, in which sewage is allowed to stand for a period of about two hours. After one dose is withdrawn the bed stands empty for aeration for four hours or so, and another dose is then introduced, three fillings a day being perhaps an average. A single contact treatment does not commonly yield an effluent sufficiently stable to discharge into a small stream. It is the general practice, therefore, to use double contact, treating the sewage first in a bed of coarse stone, perhaps one and one-half to two inches in diameter, and then in a fine bed, of perhaps half-inch material. The rate of treatment, even so, however, is much higher than that commonly used with sand beds, 500,000 gallons per acre per day against 100,000. Half an acre of contact beds would treat the sewage from a population of 2,500 against 500 for the intermittent filter. The effluent even from double contact is less highly purified than an intermittent filter effluent. It is dark and somewhat turbid, but it should be free from the tendency to putrefactive decomposition.

THE TRICKLING FILTER.

Meanwhile the problem of purifying sewage at high rates was being attacked in another and even more promising manner. The fundamental combination of bacterial films, sewage and air can be effected in various ways. The late Col. George E. Waring attempted it at Newport in 1894 by blowing air into a bed of coarse stone below, while sewage ran down through it from above. Theoretically this seems a satisfactory process, but it has not yet been demonstrated that a sufficient supply of oxygen can be economically provided in this manner. Success was finally reached along another line by resorting to the device of applying sewage, not in bulk, but in a fine spray distributed as evenly as possible over the surface of the bed. By this means the rapid flow of large streams of sewage is prevented and the liquid trickles in thin films over the surfaces of the filling material while the spaces between are continually filled with air, the oxygen content of which in practice does not become seriously exhausted. The condition is analogous to that which obtains in the process of vinegar manufacture, when alcoholic liquor is allowed to run over shavings covered with growths of acetic acid bacteria. Under the name of the trickling bed (called also sprinkling bed or percolating bed) this has come to be considered one of the most promising and effective of all devices for sewage purification.

As in the case of contact beds, almost any hard nonfriable material may be used for the construction of trickling filters. In America the size of the filling material is generally between one and four inches, and the depth of the beds between five and eight feet. Mr. Rudolph Herring, in a very enlightening review of the underlying principles of sewage treatment, has recently pointed out that there are three fundamental variables in this process of purification, air supply, total area of bacterial films and time of exposure. The area of bacterial films is conditioned by the size of the filling material and the depth of the bed (the smallest material, of course, giving the greatest surface) and the time of exposure is controlled by the rate at which sewage is applied. Reduced to its lowest terms, a trickling filter is simply a heap of stone or other material of such size, depth and texture as to support a bacterial growth sufficient for the work in hand.

The distribution of the sewage over the surface constitutes the most serious difficulty in the construction and operation of the trickling bed. In England, many of the disposal areas are equipped with mechanical distributors of great complexity. Some are designed on the principle of the lawn sprinkler, and are revolved by the propulsive force of the sewage as it is discharged. Others are in the form of great, movable weirs which pass back and forth on rectangular beds, dripping sewage as they go. At Hanley a mechanical distributor was installed for a quarter acre bed which weighed twelve tons and wore out a forty-five pound bridge rail in two and a half years.

At other English plants, like the most famous of all at Birmingham, and at most American disposal areas, the sewage is distributed by spraying it upward from fixed sprinkler nozzles. This method effects a less perfect distribution than that attained by the English mechanical apparatus, but the cost of construction and renewal is much less.

The trickling filter can be operated at a rate of 2,000,000 gallons per acre per day, or four times as fast as the contact bed. Half an acre of trickling beds would care for the sewage from 10,000 persons, while

a similar area would only do for 2,500 persons with the contact bed and for 500 with the intermittent filter. Furthermore trickling beds are practically free from the clogging which menaces the permanency of the contact process, for the suspended matter comes through trickling beds in the long run in about the same amount in which it goes on at the top, changed only in its chemical nature. The effluent is far less well purified than that of a sand filter. It is more turbid even than contact effluent, and in appearance may not even seem very different from untreated sewage; however, the essential changes have been brought about. The more unstable organic bodies have been oxidized and the effluent contains a sufficient excess of oxygen so that succeeding changes will be nitrifications and not putrefactions. At Birmingham, England, where the trickling process has been most ably and exhaustively studied, a sewage flow of thirty million gallons a day is treated, first in sedimentation and septic tanks, and then on trickling beds, having a total area of about thirty acres; and in dismissing an injunction granted against the city by a lower court the Master of the Rolls has recently decided that the effluent from the Birmingham works actually improves the character of the river into which it is discharged. The large plants recently constructed in the United States at Columbus, O. (twenty million gallons), at Washington, Pa. (one million gallons), at Reading, Pa. (two million gallons), and at Mt. Vernon, N. Y. (three million gallons) are all of the trickling type. The trickling filter is indeed an ideal mechanism for solving the essential problem of sewage disposal. It exhibits the simplicity of all scientific applications, which are merely intelligent intensifications of natural processes. A pile of stones on which bacterial growth may gather and a regulated supply of air and sewage are the only desiderata. We meet the conditions resulting from an abnormal aggregation of human life in the city by setting up a second city of microbes. The dangerous organic waste material produced in the city of human habitations is carried out to the city of microbes on their hills of rocks, and we rely on them to turn it over into harmless mineral form.

SEWAGE DISINFECTION.

So far nothing has been said about the problem of bacterial removal. In general this is a subsidiary question in sewage purification. Frequently the elimination of offensive organic decomposition is all that is necessary, and bacteria can be allowed to pass with the effluent into the stream, to be removed by the quite distinct processes of water purification from any water taken out for human consumption. Sand filtration effects a very considerable purification in living and lifeless constituents alike; but the contact and trickling beds are essentially oxidizing mechanisms without filtering action adequate for the removal of micro organisms. It is true that in the unfavorable environment of the septic tank and trickling filter, many sewage organisms do die out, but their elimination is incomplete and uncertain. If a nearly germ-free effluent is required, some special method must be adopted for bacterial removal. This particular problem has come into great importance of late in connection with the protection of shellfish industries, menaced by the sewage of seaboard cities. Fortunately there has been worked out to meet this need a simple and efficient method, a new chemical treatment, not designed as in the old precipitation processes to remove suspended solids, but merely to destroy living germs. The application of ordinary bleaching powder, or chloride of lime, in small amounts of fifteen to thirty parts of bleaching powder to a million parts of sewage, will effect a satisfactory reduction of bacteria at a very reasonable cost, as shown first by Mr. S. Rideal in England and by Prof. E. B. Phelps in this country. Baltimore, Maryland, has adopted this procedure, as have certain small towns on the New Jersey coast; and it promises to be of use in dealing with certain phases of the New York Harbor problems.

There are many questions still to be solved in the purification of sewage. The removal of suspended matter, for example, urgently demands further careful study; yet the work of the last ten years in England and the United States has blocked out the main outlines of satisfactory sewage disposal practice. The engineer can to-day successfully meet any demand for the purification of domestic sewage; and this purification may be carried to any degree of perfection for which the community in question is prepared to pay. If a clear and sparkling effluent, highly purified bacterially, is desired, he can design an intermittent filter for that purpose. If merely a stable effluent which may be discharged into a stream without creating a nuisance is wanted, he can build a trickling filter. If, on the other hand, a disinfected but not organically purified effluent is called for, that end, too, may be attained.

Multiplex Telephony and Telegraphy—II*

Electric Waves Guided by Wires

By George D. Squier

Continued from Supplement No. 1852 page 6

DUPLEX TELEPHONY, USING ONE GROUNDED CIRCUIT.

To determine the fact that electric waves of ultra-sound frequency produce no perceptible effect when superimposed on the same circuit over which telephonic conversation is being transmitted, the next step was to use such a train of sustained oscillations as the vehicle for transmitting additional speech over the same circuit. For this purpose the twisted-pair telephone line was equipped with a complete standard local battery telephone set, as installed for commercial practice, and in addition one of the wires

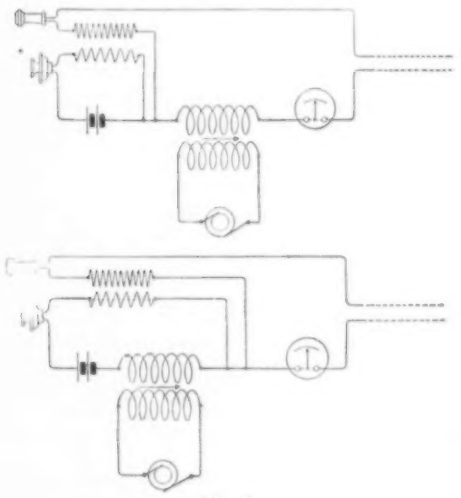


Fig. 3.

of the pair was equipped as in Fig. 1, the circuit being shown diagrammatically in Fig. 2. This particular arrangement was employed in this experiment for the reason that it was desired to have the battery telephone operate on its usual circuit with the introduction of ground connections at the ends of the line for the super-position of the high-frequency circuit. When such ground connections were introduced directly without tuning elements therein the metallic circuit experienced the usual disturbances found under city conditions, but the metallic circuit could be reduced to silence again by introducing in the ground connections the necessary tuning elements of magnitudes suited to wireless telegraphy.

Next, the twisted-pair telephone line was equipped with a complete standard local battery telephone set, as installed for commercial practice, with the exception that the local battery circuit of the transmitter telephone set was opened and a few turns of coarse wire inserted in series with the two dry cells which are normally used, as shown in Fig. 3. Inductively connected with this coil was the armature circuit of the generator. A hot wire milliammeter was placed in the line circuit to indicate the magnitude of the high frequency current which was flowing on the line. With this arrangement tests were made to determine whether or not there were any effects upon the transmission of speech, due to superimposing high-frequency currents upon the battery telephone sets. With an operator at each end of the line, using the equipment in the regular commercial way, the direct current voltage and the alternating current voltage in series with it in the primary circuit of the transmitter were varied individually and relatively in a variety of ways, with the striking result that just at the point where the direct current voltage was decreased, so that no sounds were received, the line became absolutely silent, although the alternating voltage in the circuit was at its largest value, or, again, speech would reappear at the receiving station at the moment when sufficient direct current voltage was introduced to produce it, and the simultaneous presence of both the maximum direct voltage and maximum high-frequency voltage in a circuit produced exactly the same result as the maximum direct current voltage did alone. When, however, the high-frequency current in the local circuit was forced to a point which caused "burning" in the transmitter itself, then, and then only did the high-frequency current in any way interfere with the transmission.

By transferring this coil from the local circuit of the telephone set directly into the line itself, so that the higher frequency oscillations would be superimposed upon the line beyond the iron cored induction coil of the telephone transmitter, it was not possible to detect the presence or absence of high-frequency currents.

As a test under severest conditions the effect was noted upon speech received at the same station at which the high frequency current is being impressed, for here are the attenuated telephonic currents at the receiving end of the telephone line, on which is superimposed a high-frequency current of vastly greater magnitude at the same point. No effects of any kind could be detected under these conditions. From the above experiments it appears that in any attempt at multiplex telephony by means of electric waves of ultra-sound frequencies superimposed upon the minute telephonic currents employed in battery transmission there is nothing to fear from disturbances of such currents upon the operation of the ordinary battery equipment.

SILENT EARTH CIRCUITS.

The electromagnetic constants of the apparatus employed in telegraphy and telephony over wire circuits are of the order of magnitude of microfarads and henrys, and since no attempt is made at tuning, these are constructed at present with no provision for continuously varying the units.

In wireless telegraphy and telephony these electromagnetic constants are of the order of magnitude one thousand times smaller, or are expressed in thousandths of microfarads and of henrys; furthermore, these forms of apparatus are provided with convenient means of continuously varying their values for tuning.

In the operation of providing tuning elements for earth connections there is at the same time afforded a certain means of eliminating any harmful disturb-

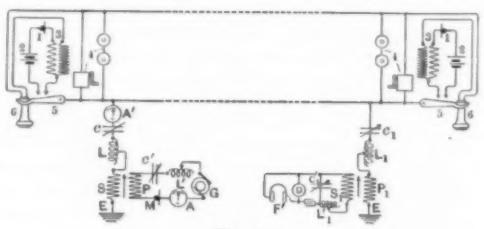


Fig. 4.

ances from the earth, for the condensers employed for tuning to frequencies above audition possess an impedance to the frequencies involved in speech and also any other disturbances from the earth, which effectively prevents the passage of any disturbance of audible frequency. These condensers offer a comparatively free passage to the electrical oscillations of the frequencies here being considered. When such earth connections are selectively tuned with the line to frequencies entirely above audition it is evident that no audible frequencies, either in the earth itself or from the line, can pass. Simple experiments proved the efficiency of this arrangement, and when the metallic telephone circuit, equipped with a standard local battery set, was connected to earth in the manner described, the operation of the battery set was perfectly quiet and equally good with and without such earth connections.

The point was now reached where the road was clear for duplex telephony, and for this purpose the apparatus and methods employed in wireless telephony were applied to one of the wires of the metallic circuit as though it were an antenna. The actual arrangement of this circuit is shown in Fig. 4, in which *G* is the source of sustained high frequency oscillations; *C'* is the tuning condenser of the oscilla-

* A paper presented at the 28th Annual Convention of the American Institute of Electrical Engineers, Chicago, Ill., June 26th-30th, 1911. Copyright, 1911, by A. I. E. E.

tory circuit; L' is the tuning inductance of the oscillatory circuit; P is the primary of the oscillation transformer; A is the ammeter; M is the transmitter microphone; S is the secondary of the oscillation transformer in the line circuit; C is the tuning condenser in the line circuit; L is the tuning inductance in the line circuit; A' is the ammeter in the line. At the receiving end of the line C_1 is the line tuning condenser; L_1 is the line tuning inductance; P_1 is the primary of the oscillation transformer; S_1 is the secondary of the oscillation transformer; L' is the tuning inductance in the oscillatory circuit; c_1' is the tuning condenser in the oscillatory circuit, between which and the telephone F' the detector D is operatively connected; E is the earth connection.

The local battery telephone sets are connected across the two lines wires in the usual manner. In both sets 1 is the microphone transmitter; 2 is the local battery; 3 is the induction coil; 4 is the ringing system, including the bell and hand generator; 5 is the switch hook; 6 is the telephone receiver.

It was found that cross-talk was heard in the audion circuit from the battery transmitter at the transmitting end when the audion circuit alone was connected directly to earth from the line without any tuning coil or condenser. If, however, the tuning condenser was inserted, this cross-talk entirely disappeared, even though the tuning coil was not inserted. This is because the impedance of the small tuning condenser is large for telephonic frequencies, while the tuning coil impedance admits these telephonic frequencies. Both elements of tuning are required for selective absorption of energy, so that the high-frequency circuit is available as an additional telephonic circuit. With this arrangement talking in the transmitter of the high frequency side of the system was heard only in the audion and there was no cross-talk from the ordinary local battery circuit. Similarly, there was no effect of the high-frequency transmission on the local battery transmission, and the two telephonic messages were completely separated. Both circuits were entirely free from earth disturbances.

The volume of speech is greatly increased at the

Fig. 5.

receiving end of the cable by the simple device of inserting the transmitter in the dynamo circuit and operating this circuit at or near resonance. In addition, the coupling at both transmitting and receiving stations should be so designed as to permit adjustment for optimum.

The frequency used in this experiment was about 100,000 cycles per second. The talk on the regular battery circuit was of the usual high standard both ways, so that the only reason at this point why complete duplex-diplex telephony was not obtained was the fact that there was no high-frequency dynamo available at the laboratory. There is, however, available at this laboratory one of the latest forms of the high-frequency arc, and accordingly this was arranged with suitable electromagnetic constants to give a period of about 71,000 cycles per second, as measured by a standard wave meter such as is now commonly used in wireless telephony and telegraphy. This source of high-frequency electromotive force was induced upon the high-frequency line wire in a similar manner to that described in the station at the Bureau of Standards, with the result that one of the wires of the twisted-pair was made to carry simultaneously the battery telephonic currents from the two transmitters, the high-frequency oscillations of about 100,000 cycles per second, applied at the Bureau of Standards, and the high-frequency oscillations of about 71,000 cycles per second, applied at the laboratory. No influence from these conditions was perceptible upon the excellence of the battery transmission and reception of speech either way.

DUPLEX TELEPHONY, USING METALLIC CIRCUIT (A) BRIDGING ARRANGEMENT.

The next experiments pertained to the standard metallic circuit as universally used on telephone toll lines in congested districts. The electric constants of this line have already been given.

The next step was to remove entirely the earth connections from the metallic circuit and superimpose both telephonic circuits upon the same pair of wires, as shown in Fig. 6, in which the high-frequency apparatus, shown diagrammatically in Fig. 5, is bridged across the line wires A and A'. G is the source of sustained high-frequency oscillations; C_1 is the tuning condenser of the oscillatory circuit; L_1 is the tuning coil of the oscillatory circuit; P is the primary of the oscillation transformer; A is the ammeter; M is the transmitter microphone; S is the secondary of the oscillation transformer in the line circuit; C is the tuning condenser in the line circuit; L is the tuning inductance in the line circuit; A_1 is the ammeter in the line. At the receiving end of the line, C' is the line tuning condenser; L' is the line tuning inductance; P' is the primary of the oscillation transformer; S' is the secondary of the oscillation transformer; L'' is the tuning inductance in the oscillatory circuit; C'' is the tuning condenser in the oscillatory circuit, between which and the telephone F the detector D is operatively connected.

The local battery telephone sets are connected across

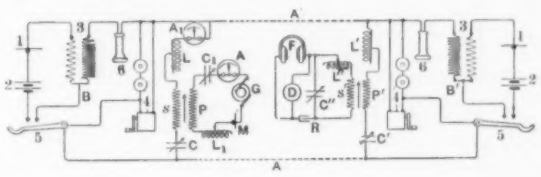


Fig. 6.

the line wires in the usual manner. In both sets, 1 is the microphone transmitter; 2 is the local battery; 3 is the induction coil; 4 is the ringing system, including the bell and hand generator; 5 is the switch hook; 6 is the telephone receiver.

Since the high-frequency apparatus as commercially developed in the wireless telegraph art was used, each of the units was variable and had been previously carefully calibrated by reference to the standards of the Bureau of Standards. The coupling coils were of the design adapted for wireless telephony, the coefficient of coupling being adjustable between wide limits. It was therefore a matter of hours to run through a large number of experiments in which various combinations were tried.

The transmitters first tried were those of the microphone type inserted in the armature circuit of the dynamo and provided with water cooling when currents of several amperes were to be used.

It was soon found, however, that the efficiency of transmission of this cable line was so good for electric waves of these frequencies that a very small current, in the neighborhood of two milliamperes, sent into the line was amply sufficient for good speech at the receiving end about seven miles distant. No attempt was made to determine to what lower limit the transmission current could reach in this respect, but such small currents enabled the ordinary telephone transmitter to be used without any provision for cooling, especially when it was inserted in the line circuit, instead of in the oscillatory circuit of the dynamo.

The telephone receivers were those regularly furnished for wireless telephony, ranging in resistance from 2,000 to 8,000 ohms.

Resonance. As was expected, the phenomena of resonance under the conditions which here obtained were very pronounced and highly consistent, since there is here a definite circuit free from the disturbances and variations inherent in radio telegraphy and telephony. In wireless telegraphy and telephony it is well known that within a few minutes transmission will drop off many fold from causes not entirely understood, and from diurnal variations and electrostatic disturbances, effective transmission is often prevented.

In general, the different circuits were tuned to resonance in the same manner, for the same purpose and with the same effect as in wireless telephony and telegraphy.

The line circuit itself was readily tuned to resonance for the particular frequency of the dynamo by noting the maximum reading of the hot wire ammeter A_1 in the line itself. This maximum is readily found by varying either the capacity C, or the inductance L, or both.

At the receiving end of the line, coil L' and the condenser C', as well as the coil L'' and the condenser C'', were tuned to give a maximum intensity of signals in the receiving telephone of the audion.

The audion, a detector of the so-called vacuum type, consists of an exhausted bulb containing (a) a tungsten filament maintained at incandescence by a current from a local battery of six volts and (b) two platinum electrodes insulated from the filament and from each other. To these electrodes, one of which is a platinum plate and the other a platinum grid, there are applied through the high resistance receivers about 35 to 45 volts from a local battery. The brilliancy of the filament is controlled by a small series rheostat, and the voltage applied to the insulated terminals by a local potentiometer.

The gases in the bulb, becoming ionized by contact with the glowing electrode, serve as a conductor of electricity, having a high unilateral conductivity. If the platinum wire grid is close to the hot filament and the plate at some greater distance, the direction of greater conductivity is from the plate through the gas by the ionic path to the grid, so that if the positive terminal of the telephone battery is applied at the plate terminal and the negative at the grid terminal, a sufficient current to operate the telephone will flow.

If the terminals of the condenser of a resonant receiving circuit are connected to the grid and one terminal of the filament, the high frequency e. m. f. impressed from this resonant circuit will cause a greater current to flow through the gas in one direction than in the other, as in the case of the direct-current potential applied through the telephone receiver. This rectifying effect will be produced in the telephone receivers, causing them to make audible the received signals.

By changing the coefficient of coupling or the potential across the audion, which is adjustable, or the amount of ionization of the gases in the tube by adjusting the current through the filament, or any combination of these, it was found that the receiving

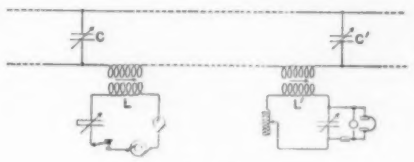


Fig. 7.

operator could bring out the speech to suit his particular fancy.

As stated above, the dynamo operated regularly at ranges from 100,000 cycles per second down to 20,000 cycles per second. It was therefore possible to try the effect of a comparatively wide range of frequencies in these experiments, covering three octaves, the inductances and capacities being chosen to correspond to each particular frequency. It was found that more energy was delivered over this particular type and length of circuit by using the lower frequencies of this range than the higher ones, although efficient results were easily obtained at any point.

The battery telephone side of the equipment was left absolutely intact, as it would be commercially used, and severe tests were made, employing four operators, to determine the efficiency of two simultaneous conversations over this same pair of wires.

The ringing circuit was operative both ways with no apparent effect on the high-frequency telephone transmission. This ringing circuit develops a comparatively large alternating current flowing in the wire at about 30 cycles per second and at a voltage of many times that of either the high-frequency or the battery side of the circuit.

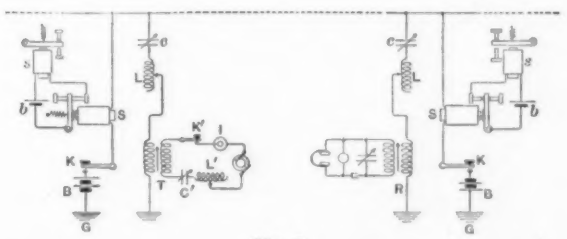


Fig. 8.

Articulation tests, including music, numerals and other difficult combinations, gave satisfactory results, with no interference whatever between the two sides of the circuit.

By holding one telephone receiver to one ear and the other receiver to the other ear, the receiving oprator could hear two entirely different conversations simultaneously over the same pair of wires.

(B) SERIES ARRANGEMENT.

A circuit was next made up with high-frequency apparatus inserted directly in the line in series, instead of in the bridging arrangement shown in Fig. 5. The circuit used is shown diagrammatically in Fig. 8, in which L and L' are the secondary coils of the transmitter and receiver, respectively. C and C' represent variable condensers of the order of magnitude used in wireless telegraphy and serve as low impedance paths for the high-frequency oscillations, and at the same time prevent the short circuiting of the low-frequency battery telephone current. It was found that this arrangement gave apparently as good results as the bridging arrangement of the circuit.

III. DUPLEX-DIPLEX TELEGRAPHY.

Having described in detail the experiments for obtaining the simultaneous transmission of two telephonic messages over a single circuit, it will be apparent that the problem of transmitting two telegraphic messages over the same circuit may be solved by methods and apparatus, as far as the high-frequency side of the circuit is concerned, which are practically identical with those described above.

In this connection the metallic circuit referred to was equipped with a standard Morse set for manual operation, and upon this circuit was superimposed an equipment for transmitting in one direction telegraphic messages by means of sustained high-frequency oscillations, employing the telephone as the means for receiving the signals. The circuit used is shown diagrammatically in Fig. 7, in which, in the Morse set, there are shown between the line wire and the ground G, the line relay S, the key K, and the line battery B; and the local battery b and the sounder s; and in which, in the high-frequency set, are similarly shown between the line wire and the ground G the tuning elements C and L; and at the transmitting end the oscillation transformer T, the primary of which is in circuit with the dynamo as a source of sustained oscillations, the telegraph key K', the interrupter 1 and the tuning elements C' and L', and at the receiving end the oscillation transformer R in the secondary circuit of which are included the usual tuning elements and operatively connected to them the detector and its telephone as a means of receiving the signals.

As noted in the case of the preliminary local circuit tests, it was found that over this particular line it was not necessary to use a detector for electromagnetic waves, since enough energy was delivered to operate the telephone receiver directly without any tuning by connecting it between the line and the earth.

The sound produced, however, was characteristically different in the two cases. With the detector the individual signals and the characteristic tone corresponding to the interrupter at the transmitting end of the line, whereas without the detector this tone was entirely absent, and a general dull sound, due to the resultant action of the wave-trains, was heard. If, however, a telephone receiver was employed with a soft iron core, instead of a permanent magnet, no result was obtained with the limited power used on this line.

Although little mention of telegraphy by high-frequency electric waves has been made thus far, as a matter of fact it was found convenient during the experiments upon telephony actually to employ telegraphy as a quick and ready means of determining resonance between the circuits in each particular case.

When any particular arrangement was being employed the first steps were invariably to send simple Morse signals over the circuit until the operator at the distant end of the line reported maximum loudness in the receiving telephone, which indicated that the terminal apparatus with the line circuit was properly tuned. This being accomplished it was only necessary to throw a switch, which substituted for the automatic interrupter and telegraph key, the telephone transmitter. The experiments could then proceed on telephony without any material change being made at the receiving station. Telephony and telegraphy thus proceeded hand in hand as a mere matter of convenience, and one of the practical advantages in the use of electric waves for transmitting intelligence is that the whole set-up of apparatus is practically the same for each and they can be used interchangeably over the same circuit.

Considering the Morse equipment, indicated in Fig. 8, the electromagnetic units involved are of the order of magnitude of microfarads and henrys, and the period of the direct interrupted current for Morse sending is not more than the equivalent of about 10 complete cycles per second, whereas in the high frequency side of the circuit the electromagnetic units are of the order of magnitude of thousandths of a microfarad and of thousandths of a henry and with frequencies not less than 2,000 times greater than those involved in manual Morse sending. Furthermore, the ohmic resistance of the line which plays a prominent part in limiting the distance and speed of Morse working, is comparatively unimportant in the case of electric waves guided by wires. The operation of the line equipped as in Fig. 8 was perfectly satisfactory, there being no perceptible interference between the two messages in either direction.

Since the standard telegraph circuit of the world uses a ground return circuit, this same equipment was arranged to operate on one of the wires of the twisted-pair in the telephone cable as such a circuit with earth connections at each end, and its operation was equally successful.

Since it is a well known characteristic of high frequency apparatus used in tuned circuits that there shall be no iron involved in the circuit, it is evident that in cases where such a high-frequency circuit is to be superimposed upon a line comprising way-stations, where line relays are inserted directly in the circuit, it will be necessary and sufficient to shunt such way-stations by condensers of the order of magnitude of thousandths of a microfarad. Such condensers offer a comparatively free path for the high-frequency electric waves, but interpose a practical barrier to the Morse frequencies.

The same general statement can be made relative to any of the standard forms of low-frequency telegraphy over wires as now practiced, such as the polar duplex, the differential duplex, and the duplex-diplex employing alternating currents of low frequency and standard keys, relays and sounders.

Inserting a regular 150-ohm telegraph relay in series in the line cuts down the high frequency current to a small percentage of its original value, which indicates the marked influence of the presence of iron in such a circuit. Furthermore, it was noted that at 100,000 cycles the hysteresis of the iron core at this period was so great that it became heated very perceptibly in a few moments.

Since a portion of the telegraph lines now used is still composed of iron wires, it would be expected that electric waves would be propagated over such wires less efficiently than over copper wires, since it is well known that electric waves penetrate only about one-thirteenth as deeply into soft iron for a given frequency as into copper, although this is modified by the fact that the iron in telegraph wires is not soft iron and in addition is galvanized.

(To be continued.)

Radiant Energy and Matter—V*

Sir J. J. Thomson's Royal Institution Lectures

Continued from Supplement No. 1852, page 7

In commencing his fifth lecture on the above subject at the Royal Institution, Prof. Sir J. J. Thomson, F.R.S., said that on the last occasion he had alluded to certain experiments made by Tyndall on the absorption of long wave-length radiation by various vapors and gases, such as water, ammonia, and carbon dioxide. All of these Tyndall had shown, absorbed, very readily, radiation in the infra-red portion of the spectrum. So far as water vapor was concerned Tyndall's results had been disputed by Magnus, but it had since been proved that Tyndall was perfectly right in every one of his contentions. The fact that water did absorb long-wave radiation was, the lecturer continued, of very great importance from a meteorological standpoint. The atmosphere, with its content of water vapor, acted as a trap for the low-temperature radiation from the warmed earth, which otherwise would radiate into space very freely. The presence of water vapor checked this, however, and as a consequence the temperature did not fall so rapidly after sunset as it otherwise would. Since the experiments of Tyndall many other investigations had been made on the absorption of radiation by various vapors, and as a consequence we now knew, Prof. Thomson said, not merely the total amount of this absorption, but also the particular kinds of waves which were absorbed in different cases. This long-wave absorption was "selective," radiation of particular wave-lengths being stopped while other wave-lengths got through with comparative facility. Thus, if "infra-red light" was sent through various solutions, the absorption was confined to particular waves, the wave-lengths selected being different with different solutions.

To illustrate this the lecturer passed the ordinary spectrum through a solution of didymium, and showed that, in consequence of selective absorption, certain colors were missing in the spectrum as finally shown on the screen, being replaced by dark bands. By taking a solution of another salt of didymium, the lecturer showed further that the effect was not the same in both cases, bands now appearing in the blue, while some, prominent in the previous experiment in other regions of the spectrum, were now missing.

These, the speaker continued, were cases of selective absorption in the visible spectrum, but if the larger, and in some respects more important part of the spectrum on the infra-red side, was investigated, quite similar phenomena were observed. If the wire of a bolometer were placed in successive portions of a spectrum produced by passing light first through a rock salt prism, and then through an absorbing vapor, definite positions would be found in which no current passed through the galvanometer attached to the instrument. Maps thus made of absorption spectra showed some very interesting relations between the chemical composition and the position of the lines of absorption. This, he proceeded, was well shown by the researches of Mr. W. W. Coblentz, of the Bureau of Standards, Washington, who had proved that bodies of similar constitution produced absorption in nearly the same regions, so that similarity of chemical composition was accompanied by similarity of absorption spectra. Mr. Coblentz had further shown that certain bands were associated with the presence of certain radicals, and had tabulated his results as follows:—

Radical.	Position of Absorption Band.
CH_2 or CH_3	3.43 μ,6.86, 13.6 to 13.8, 14.0.
NH_2	2.96 μ, 6.1, 6.15.
NO_2	7.46 μ, 9.08.
C_6H_6	3.25 μ, 6.75, 8.68, 9.8, 11.8, 12.45.
OH	2 45 μ.
NSC	4.78 μ.

Many of the wave-lengths measured, Prof. Thomson remarked, were nearly the octaves of others in the same series, but the speaker said he did not think that much importance was to be attached to this circumstance. The bolometer wire, fine though it was, was still coarse compared with the width of the bands, and it was thus almost impossible to get the true position of a band with sufficient accuracy. In the early days of spectroscopy, he went on, when methods of measurement were less exact than they had since become, a great number of harmonics had been noted among the spectral lines. As precision increased these had practically all disappeared, and he thought that the suggestion that absorption bands were often octaves of others in the same series was open to grave suspicion.

Many absorption bands, the lecturer proceeded, could also be obtained as emission bands. Thus, if water were heated, it gave out a banded spectrum, the bands of emission occupying the same position as the absorption bands already described. Evidently therefore, water contained something which had the power to vibrate with a period corresponding to the absorption bands. This might, of course, well be expected, but this question of the relation between absorption and emission was, he thought, often unduly simplified in the text-books. Here it was often thought enough to say, that absorption arose, when a body contained a system, which could vibrate in time with the disturbance passing through or by it. This condition was a necessary one, but in itself was not sufficient to account for absorption spectra. An analogy was often drawn between the production of an absorption spectrum, and the effect on sound, of a screen of tuning-forks placed between the ear and the source. If these forks were all in unison with the sound, it was quite true that they would enfeeble the sound to an ear which they screened from the source, but at the same time they would make the sound stronger elsewhere. Hence, what was obtained in this case was not a destruction of the sound energy, but rather a scattering of it. This, in fact, was exactly what would be obtained in the corresponding case in optics, if resonance alone was involved in the phenomena of absorption. The result would then be, not absorption as we knew it, but a scattering of the light, such as occurred when light passed through ground glass or a layer of fog. In absorption, on the contrary, there was a definite destruction of the light, which was turned into something

* Report taken from *Engineering*.

else. Some mechanism was therefore needed to transform light energy into energy which was not light. In the most usual case the light energy was transformed into heat. This, for instance, was probably the case when light was absorbed by passing it through sodium vapor. Probably the mechanism concerned in this transformation was capable of working both ways, and would therefore be capable of transforming heat into light. Hence it was to be expected that emission bands, corresponding to the absorption bands, would readily be produced by heat. Nevertheless, it turned out that not all lines in the spectrum could be produced by the mere action of heat. Hydrogen, for example, required to be excited by some other means than heat to produce the lines of its spectrum, and, similarly, ordinary hydrogen would not absorb these lines. When, however, there was a strong absorption, the reciprocal action might confidently be expected.

It was, the lecturer continued, interesting to note that most of the lines which could readily be reversed could be produced by mere heating. Some lines, however, were exceedingly difficult to absorb. Thus a long tube filled with hydrogen showed no special absorption of the hydrogen lines—at least, so long as the molecules of the gas were in their normal state. Reciprocally these lines could not be produced by thermal means.

As already stated, in cases of absorption the light energy was most usually transformed into heat, but in certain cases the light produced chemical decomposition. In such cases, Prof. Thomson said, the energy of the light was destroyed by chemical means.

To illustrate this the lecturer repeated an experiment of Tyndall, in which a strong beam of light was passed through a glass vessel containing vapor of amyl-nitrite. At the outset a screen filled with liquid amyl-nitrite was interposed between the source of light and the vapor under experiment. So long as this screen remained, the light which succeeded in passing it had, the lecturer showed, little or no action on the vapor. On removing the screen, however, and letting the unfiltered rays act on the vapor, a cloud was produced, due to the decomposition of the amyl-nitrite by the action of the light, the energy of which was in this case converted into that of chemical separation.

As another example of such a reaction the lecturer reproduced an experiment due to Mr. C. E. T. Wilson, who had shown that, when ultra-violet light was passed through vapor-laden air a cloud was produced. Here, again, the lecturer stated, there was a transformation of light energy into chemical action. Mr. Wilson's explanation was, that under the conditions stated, hydrogen peroxide was formed. This was very readily absorbed in water, so that drops in the vicinity became solutions of hydrogen peroxide. Such solutions had lower vapor pressures than pure water, and thus evaporated less readily. In consequence they grew in size, and ultimately produced a visible cloud, as shown in the experiment.

Was there, the lecturer proceeded, any way of distinguishing whether, in cases of absorption, light was transformed into heat or into the energy of chemical separation, when the products of the latter were insufficient to be colected? One criterion, he went on, was given by the connection which existed between absorption and radiation. If the energy were converted into heat, no permanent change was made in the constitution of the body, and the ordinary laws governing emission and absorption would then apply. If, on the other hand, chemical changes occurred, the fact that the bodies were altered made these laws inapplicable.

Now the connection between absorption and radiation was that for each and every wave-length the radiation from a black body was the maximum possible at its temperature. No body could absorb more radiation of any kind than a black body, since the latter absorbed all there was of every kind. Hence, conversely, no body could radiate more of any particular kind than did a black body at the same temperature. If therefore, in a given case, a body emitted radiation which was stronger in light of a given wave-length than "black" radiation, then this would be evidence that chemical changes were going on. Thus, if a "black" 'wire placed in a salted flame gave a spectrum which was as strong in the yellow as the rest of the flame, no chemical action was concerned in the production of the D lines. On trying this experiment Paschen, the lecturer said, had estimated that the brightness of the *D* line in a salted flame was twice as great as that in the spectrum obtained from a platinum wire at the same temperature. More recently, however, Dr. Bower, trying a great number of different salts, had come to the conclusion that there was no difference in the brightness. Were this confirmed, it would, the lecturer said, be a strong argument in favor of the view that the light energy absorbed by sodium vapor was directly transformed into heat.

There were many cases, he proceeded, in which light of definite wave-lengths was emitted, such as by a sodium flame or by a vacuum-tube carrying an electric current and giving a bright spectrum accordingly. The question that then arose was whether all the particles in the flame or in the tube were luminous, and acting as lamps, so to speak, or whether the luminosity was confined to a small fraction of the whole number of molecules present? In other words, was luminosity due to the presence not of normal molecules, but of systems produced by the agency which excited the luminosity?

An answer to this question could, he proceeded, be founded on a certain connection between the refractive index of a body and the kind of light it was capable of emitting. It was, in short, not difficult to show if light, as there was now no question, originated in the motion of electrified bodies, that a relation could be found between the refractive index for waves of infinite length (that was to say, the square root of the specific inductive capacity of the body) and the kind of light it was capable of emitting. The connection, the lecturer stated, was as follows:—

$$\mu^2 = 1 + \Sigma \frac{N}{4\pi} \cdot \frac{e^2}{m} \cdot \lambda^2$$

Here N denoted the number of active particles or "lamps" in unit volume, e the charge of the particle, m its mass, and λ the wave-length emitted. If there were a number of lines in the spectrum, there would be a corresponding number of values of λ, and hence arose the introduction of the sign Σ.

In the case of a complicated spectrum, Sir Joseph continued, if N were put equal to the number of molecules in unit volume, the value then obtained for μ^2_∞ was out of all proprtion too great. It should be added, he observed, that the number of terms, under the sign of summation, depended not upon the number of different kinds of waves actually being given out at any time, but on the number the body was capable of giving out.

If, however, the number of "lamps" were very small compared with the total number of molecules, the expression given above for μ^2_∞ would agree with actual experiment, and hence it might be concluded that in a salted flame not every particle of sodium emitted light, though it might be turned into a system which could do so. The importance of the term contributed to the expression for μ^2_∞ became very great in the case of wave-lengths such as 108 μ, so that it was evident that only a small fraction of the molecules could be luminous at any instant.

Futher evidence in support of this conclusion was afforded, he went on, by the appearance of the spectrum itself. As regarded the constancy of the wave-lengths emitted, such spectra were very definite, but the relative intensity of the various lines varied enormously with the conditions of the experiment, and this was most in accordance with the view that lines were produced by special systems, and not by the normal molecules. It was, in fact, almost a case of "one man one job," or, at any rates, of one system for each series of lines, if not for each individual line.

As stated, the period of vibration was a constant, the lines not shifting with changes of temperature, though the intensity of the lines did vary. Yet if a tube were filled with hydrogen, even under high pressure, it would show no selective absorption of the hydrogen lines. If, however, a current were passed through the hydrogen the latter became capable of absorbing some of the hydrogen lines, so that the current apparently made, out of the hydrogen, something which was not hydrogen itself, but which constituted the "lamps," which could either emit or absorb the hydrogen lines. How far similar conditions held for infra-red spectra there was as yet no evidence; but even here he believed it would be found that not every molecule in a vapor had the power of selective absorption but only peculiar aggregates of them. Something of this sort indeed was suggested by the experiments of Rubens and Wood, who compared the absorption of water in a liquid form with that of its vapor. Using waves 1-10 mm. long, they found that a film 1-7 mm. thick was completely opaque to such radiations. An equal number of molecules of vapor arranged in a column many feet long proved, however, to let through more than 20 per cent. of this kind of light. Hence, with water in the liquid form there were apparently complexes present which were specially fitted to absorb this type of radiation.

He had already stated that in absorption, light energy might be transformed either into heat or into the energy of chemical separation. There was, however, yet another alternative, in which light of a particular kind was absorbed and turned into light of a different kind, as in the phenomena of phosphorescence. To illustrate this the lecturer passed a beam of light through an exhausted bulb, in which were a few particles of iodine. Inside the bulb the iodine vapor was shown to phosphoresce with a yellowish light. Making the experiment with monochromatic light, Profesor Wood had, the lecturer proceeded, shown that this monochromatic light was turned into monochromatic light of a different kind. The phosphorescence of iodine, Professor Thomson added, was one of the few exceptions to Stokes's law, according to which the light emitted, in cases of phosphorescence was always of longer wave-length than the light which excited the action.

Norgine, a New Vegetable Gelatine

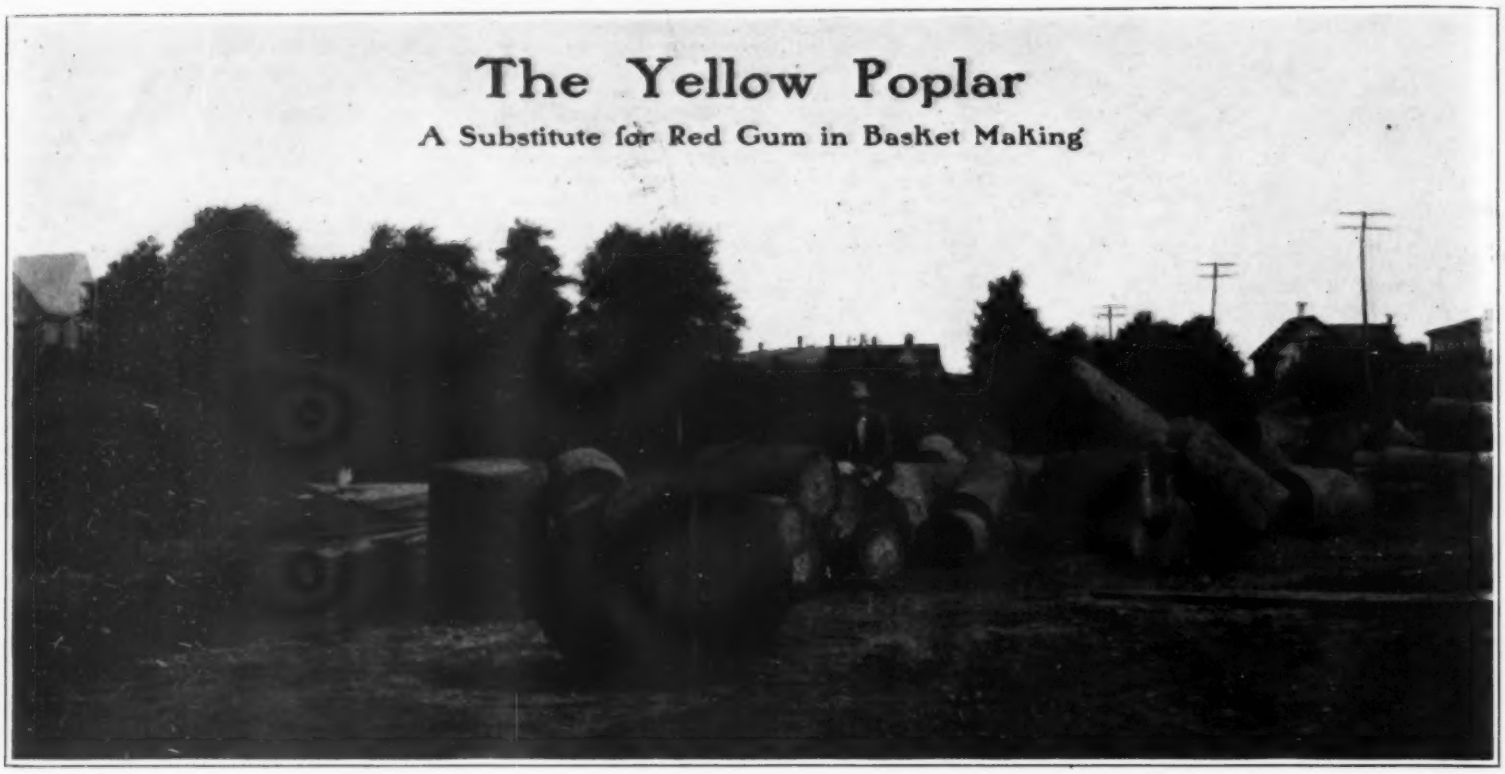
GELATINE or like products come from both the animal and vegetable kingdoms, but we are less familiar with vegetable gelatines. One of the most recent of these latter products comes from Norway, and is known as "norgine." It does not appear to be used as food, however, but for other purposes. When it is purified and bleached it can be used for sizing of cloth or for like preparations. It is extracted from several varieties of sea weed, such as the Laminaria and the Saccharinus, which are abundant on the coast of Norway. A solution containing but one-twentieth of it will give a jelly-like mass, so that it is very strong and only a small amount of it is needed. The commercial product is in the form of small grains or scales of irregular shape, somewhat like broken up gelatine, and the grains have a brownish color which becomes lighter when the substance has been bleached. When put in water, the grains swell and then give a thick solution resembling the usual gelatine solution, but this is stronger than what ordinary gelatine will give for an equal weight. Norgine is of interest in many ways, from a scientific as well as an industrial standpoint. Certain kinds of sea weed which have a sweetish taste and contain gelatine have been used as food for a long time past by the poor populations on some of the European coasts, and they also prepare a kind of jelly in this way. It is probable that many of the products which are on the market for making jellies or quick-setting creams are nothing else than dried gelatine prepared from sea weed. In Japan the use of such sea weeds is well known. Some kinds of gelatine are used as food, while others give a kind of glue or else products for sizing purposes for fabrics. This has been a large industry in Japan from ancient times, and some of the food products are even beginning to be used in Europe. Several kinds of sea weed are even cultivated for this purpose. One of the products is known as *kanten*, and it is prepared with sea weed known as sekkasi, which grows in the island of Yeso. Gelatines for food are given by it, and it is used to thicken the *sake* wine. It also serves as a sizing or glue for paper and for sizing cloth and various other purposes. Birds nest soup is imitated by this substance. In 1908 there was produced 1,500 tons of it, valued at $240,000. Another variety is the Kombu, which consists of a sea weed growing in the north of Japan prepared for use as food. No less than $480,000 worth of it was produced in 1906. A product known as amanori is given by a sea weed (*Porphyria lacinata*), which is cultivated in many places on the coast of Japan, but especially in the bay of Tokio and near the Island of Hiroshima. It yields about $1,000 per acre.

A New Paris Double Track Iron Tube Tunnel

AN iron tube tunnel for double track is to be used for the first time under the Seine, upon the electric subway section from the Place de la Concorde to the Auteuil district. It is now being constructed at a point near the Concorde Bridge, using the compressed air shield system. Not far from this point is the double tube, each carrying a separate track, in which the trains are now running. The present tube is built up of cast iron rings and each ring in turn is made up of voussoirs bolted together. The tube has 23 feet 10 inches inside diameter, and it runs in a double curve between two shore stations, one of these lying under the Place and the second on the left bank of the Seine near the Invalides-Versailles electric railroad depot. The iron tube has a total length of 2,046 feet, and the principal curve is 825 feet radius. As the tube runs down from both banks and lies about on a level under the Seine, it is curved both in the horizontal and vertical sense, so that conical rings of special form had to be used in order to make up the curves. The construction work is carried on by the Daydé-Pillé firm of Paris. In order to secure the supply of water under pressure for the twenty-seven hydraulic jacks of the shield and also the compressed air, a large plant is erected near the Seine, and it contains air-compressors and pumps which are all driven by electric motors, using current which comes from the city underground mains. In the plant are installed four Ingersoll compressors for low-pressure and one compressor for high-pressure, of the 220 horse-power size; also two pumps for the water supply. These are all driven by belt from three-phase electric motors.

The Yellow Poplar

A Substitute for Red Gum in Basket Making



EVERY year millions of feet of red gum (*Liquidambar styraciflua*, Linn.) are boiled and cut into veneer in New Jersey, Delaware, and Maryland for making berry and fruit baskets. Many acres of forest land are being culled of their red gum trees and the logs hauled to the nearest railroad station and transported to the mill to be cut into short blocks and boiled. Thousands of cords of red gum are thrown into great boilers or vats, and left to stew until every fiber of the wood is soft and almost tender. This boiling prepares the logs for the keen-edged knives, which cut them into thin veneer from which berry boxes, fruit crates and baskets are made. The consumption of red gum for this purpose is so great that the wood is becoming scarce and high in price. The buyers for the Delaware and Maryland factories can no longer get all their red gum from owners in the vicinity, but they must go as far south as the Carolinas for their supply of logs.

The red gum has properties that no other wood in the United States possesses, and from the standpoint of the basket maker is unsurpassable, enabling him to turn it into almost anything he wants. For this reason its scarcity means a good deal to the berry and fruit basket makers. Another wood with almost similar grain, texture, and density is the yellow poplar (*Liriodendron tulipifera*, Linn.), but this wood is not so tough as red gum. Yellow poplar is also becoming very scarce, and is already much higher in price than red gum. The magnolia or cucumber tree (*Magnolia acuminata*, Linn.) has properties almost similar to the red gum, and is even slightly tougher and therefore more suitable than the yellow poplar, but it does not occur in large enough quantities to supply the demand of the basket makers. The supply of the woods commonly used for basket making is thus exhausted. Yet baskets must be made. The demand is increasing and not decreasing, and how are the manufacturers going to meet this demand without a suitable substitute for the red gum?

The solution to the problem is not quite so easy as in other branches of manufacture. When the furniture manufacturers discovered that the red oak (*Quercus rubra*, Linn.) was becoming scarce, other oaks of nearly similar properties were exploited and found suitable. The Texan oak (*Quercus texana*, Buckl.) is now extensively used in place of the true red oak and hardly one in ten thousand knows the difference. This, however, is not possible in the case of the red gum, for it is a monotypic species, and its nearest relative in this country is the American witch hazel (*Hamamelis virginiana*, Linn.), which does not attain sufficient size to be suitable for substitution. The question of a desirable substitute must be solved, and there surely are some woods in this country that can successfully take the place of red gum for making fruit baskets. Two of these possible substitutes are species which yield wood with structures and physical properties resembling red gum and which with proper treatment can be made to serve in place of it. These two woods are water gum (*Nyssa biflora*, Walt.) and cotton gum (*Nyssa aquatica*, Linn.), both of which are generally restricted to imperfectly drained soil from southern Virginia southward to Florida and westward to Texas. They furnish very important woods, which recently gained prominence commercially and are now being used extensively for a great variety of purposes. These two woods are members of the Dogwood family (*Cornaceæ*) to which the well-known large flowering dogwood tree belongs. Botanically they are as unlike the red gum as an oak and an ash. They have remarkably twisted fibers, which render the timber difficult to split, and are, therefore, much used for making articles requiring resistance to sudden strain. The wood of both of these species is very cross-grained and is liable to warp and twist, a tendency which can be overcome only by proper handling.

Since red gum began to run short necessity gradually forced the cotton and water gums into the markets where formerly they had no standing. They were also two of the first substitutes for yellow poplar and were put forward under the name of bay poplar by certain dealers in the Carolinas. They bear a very close resemblance to red gum in their structural characteristics.

Now that the scarcity and high price of red gum force the basket makers to substitute another wood, it seems that the choice should fall upon these two gums, of which there is a supply that will last indefinitely, for it is estimated that the total stand of cotton and water gums in Louisiana alone is over four billion board feet.

RED GUM TWENTY YEARS AGO IN SOUTHERN MARYLAND

SHORT CUT LOGS ON THE WAY TO BASKET FACTORY

THE YELLOW POPLAR

The Bells of Pisa's Leaning Tower

THE danger which for the last few years has been supposed to threaten the fall of the famous leaning tower of Pisa has led to investigations concerning the various influences which might hasten or increase this danger—of a fall or of serious changes in the structure.

Father Alfani, whose researches in connection with the recent earthquakes are well known to all physicists, has made a thorough investigation of all the conditions and especially concerning the influence of the bell ringing upon the stability of the world-famous structure. The result of his inquiries and experiments are that the bell ringing in no wise endangers the firmness or solidity of the leaning mass of masonry. He used an instrument which recorded continuously on a tenfold enlarged scale on a rotating drum any movement of the structure from the absolute perpendicular.

In the tower there hang five bells, of different weights, which Father Alfani had rung, each separately, and then in pairs, in order to note the different effects of their vibrations, singly and combined; and his experiments were repeated on each of the many stories of the high building. Two of the bells, the "Assunta" and the "Crocifisso"—the heaviest of the

five, which weigh 2,300 and 3,440 kg.—5,060 and 7,568 lbs. average respectively—swing the entire tower with them, like an immense inverted pendulum. If they swing so that their openings are either simultaneously outwards or simultaneously inwards, the effect of the movement of each alone is increased; but if they swing in opposite directions, the effect on the tower is only that of the difference of the two single ones tending to shake it from the present position; and this difference seems to be but slight. During the ringing, the tower not only bends as a whole, but "sticks out its breast" as Alfani expresses it. The records made in the drum are not regular curves, but jagged lines.

Alfani made similar experiments in Florence in 1903 on the tower of the Palazzo Vecchio, but there the graphical records were regular curves,—accounted for by the fact that the tower in question is vertical, while that of Pisa leans. The most remarkable circumstance in connection with the vibration of the latter tower is that it may be said to have a tendency at each vibration to raise itself out a trifle from the ground, and then to recede, so that the lowest story "swells out" as above mentioned. The amount of these variations in the upper portions of the tower, where the bells hang, is very slight; in fact only 1.8 mm. or say three hundredths of an inch; an amount which can have no effect on the stability of the structure.

We can assume the report of Alfani as worthy of credence, as he is the highest authority in Italy in seismography, and has very accurate instruments. The device which he used in his experiments on the tower is so sensitive that it records the effect of strong puffs of wind on the verticality of the tower.

Port Improvements at Hyogo-Kobbé

THE port of Hyogo-Kobbé is to be transformed so as to become one of the principal ports of Japan. In 1867, when it was opened for international commerce, it was used only for the fishing trade and handling of coast freight, and the town was of small size. Since then it has increased so that the total amount of operations up to 1908 is $136,000,000. The reason lies in the natural advantages of the port, and it is one of the largest and safest of Japan. It was decided not long since to improve it by important work, which will take ten years to carry out, and is to cost about six millions, and when this is done it will be one of the finest ports in the world. New embankments of 65 acres total surface will be built, and these will lie at 12 feet above low tide. Four jetties will run into the port, each having 1,200 feet length and 330 feet width, and between them will be basins from 500 to 550 feet wide. The anchorage depth is at least 35 feet. This will allow for anchoring nineteen ocean steamers, and there is space enough to handle at least 2,300,000,000 tons of freight annually.

COTTON AND WATER GUMS GROWING IN THE WATER IN SOUTHERN LOUISIANA

A MACHINE FOR CUTTING RED GUM INTO STAVES

THE TRANSPORT OF LONG LOGS TO BASKET FACTORY

LOGS AT FACTORY READY FOR THE BOILERS

STORE HOUSE FOR BASKETS BEFORE SHIPMENT

THE YELLOW POPLAR

Ocean Magnetic Work—II*

Some of Its Problems

By L. A. Bauer

Continued from Supplement No. 1852, page 3

It may be remarked here also that for rapid shore work, e. g., for the purpose of examining into pronounced local disturbances, the L. C. dip circle has been converted into a universal instrument by the addition of a telescope, thus making it into a theodolite, and a compass has been attached with which declinations may be determined within 2′ or 3′, or the dip circle quickly set with it in the magnetic meridian.

The Germans, as far as known, have done nothing to perfect this invaluable instrument. It was used on the "Gauss," but the observer was not satisfied with it; he may have had an inferior instrument. An accuracy sufficient for all purposes is being obtained by us with the improved instruments.

In addition to perfecting the instrument in itself, special experiments have been in progress with the view of disclosing the cause of outstanding errors. There is no great difficulty in perfecting a magnetic instrument which shall admit of observations with the desired absolute accuracy over a *limited* region, but when it comes to insuring the same accuracy over practically the entire globe, then problems present themselves scarcely to be appreciated by an observatory magnetician. Even for land instruments the problem is not such a simple one as has been repeatedly found.

Accordingly, great stress has been laid in our work not to overestimate the absolute accuracy obtained, but, on the contrary, continually assume that the desired accuracy is not being reached, and, hence, that it is of the utmost importance to get independent checks in every possible manner. Thus not only has every opportunity been embraced in port to get shore intercomparisons between all ship instruments and land outfits (our own as also those of local observatories), but there has been devised special testing appliances at Washington. One of my assistants, Mr. P. H. Dike, constructed a special dip circle testing apparatus which made it possible to examine at Washing the behavior of a dip circle for the entire possible range of dip from + 90 degrees to — 90 degrees.

One peculiarity of the dozen or so L. C. dip circles which have come to my notice has not yet been explained, but is receiving attention, viz., well nigh invariably the dip needle corrections are *negative* on good land dip circles or approved earth inductors. This correction may be as much as 5′ and more—hence the need of the continual control spoken of in the previous paragraphs. In these instruments the house in which the needle swings is of brass, whereas in land dip circles it is of wood. Throughout my experience covering magnetic instruments of every type and make, I have not yet found one—be it a magnetometer or a dip circle—that has turned out satisfactorily if the magnet house is of brass. Accordingly our next experiment will be to replace the metal house of the L. C. dip circle by wood to see whether the rather large absolute corrections can thus be avoided. The possibility of a better way of mounting the needle than in jewels is receiving attention. Furthermore the inductor is to be tried at sea.

DEFLECTOR FOR HORIZONTAL INTENSITY OBSERVATIONS.

Early in 1905, on account of the failures met with the L. C. dip circle in getting total intensities in low magnetic altitudes, as above reported, I understood the devising of a special deflecting apparatus, used throughout the "Galilee" work, which could readily be attached to the ordinary navigation compasses. At that time Bidlingmaier's "double compass" had not been perfected and even if it had it would not have answered our requirements. We desired the simplest possible contrivance both from an instrumental standpoint and that of computation.

Accordingly there was developed a deflection arrangement based on the sine-deflection formula, which implies that the deflecting magnet is at right angles to the deflected one when the state of equilibrium has been reached. Instead of mounting the deflecting magnet off on the side, as is done in land magnetometers and also in Neumayer's "deviations magnetometer," used on the "Gauss," we mounted it vertically above the center of suspension of the compass card.

The magnets were especially selected ones which could be quickly attached in a rigid manner to the deflector framework for horizontal intensity work and again readily removed for declination observations. In the Bidlingmaier instrument both the deflecting and deflected magnet systems are movable compass cards and the instrument, for best success, ought to be treated entirely as an instrument by itself. In our device the same instrument used for navigation of vessel, or for getting magnetic declination, can be converted in an instant to a horizontal intensity instrument and the design of not multiplying instruments unduly may be carried out.

Furthermore when the Bidlingmaier instrument has been tested over a sufficiently large region as, for example, the Pacific Ocean, it is very likely to be found that the instrumental constants will be subject to greater changes than he now thinks possible. In his instrument the axes of the two magnet systems are not at right angles, and in order to reduce the theoretical formula to a workable form, it is necessary that the two systems bear and maintain certain definite relations to one another.

His instrument possesses apparently, however, one advantage over ours, viz., he is independent of the ship's head or constancy of direction of lubber line, since the angle made by the axes of the two compasses is at once twice the deflection angle. In our device it is necessary to read the deflected positions of compass from some zero or index—as the lubber line—which moves as the ship turns. To overcome this difficulty two methods have been followed leading practically to identical results:

The helmsman is ordered to hold a given course to the best of his ability for about an hour, during which numerous deflection readings are made in four positions of magnet and circle. It is remarkable how at the end of a half to a whole hour the effect of yawing of ship is eliminated, the yawing being on the average as much to port as to starboard. Hence, while individual deflection set may be quite erroneous, the average yields an horizontal intensity result comparing favorably with that derived from the dip and the total intensity observed with the L. C. dip circle.

A method which has been more generally employed is to take simultaneous readings of the ship's head with the steering or other spare compass close by and then apply the necessary corrections to the observed deflection angles. Thus the agreement in the individual sets has been improved though the final result is practically the same as by the first method.

Furthermore, on the "marine collimator compass" aboard the "Carnegie," it has been arranged that the deflection angle can be read using as index some object outside the ship, e. g., the sun or a star, and thus the motion of ship entirely eliminated. Instead of an actual celestial body it is hoped soon to substitute an artificial device. Thus the difficulties due to a moving zero from which deflection angles are counted can be entirely overcome without giving up the fixed principles started out with—simplicity and ready adaptability to a variety of purposes.

Examining some of Bidlingmaier's observations closely it appears his magnet systems swing through large enough arcs, especially when the sea is not smooth, to compel him to go through the same laborious method of multiplying observations for a desired degree of accuracy as we are obliged in order to eliminate the motion of the lubber line. Compare, for example, his individual readings for station 7, November 23rd, 1906, on the "Poseidon" when rolling heavily.

It would be a simple matter to pick out deflection observations made on the "Galilee" which apparently possess the same accuracy as those claimed by Bidlingmaier for his instrument over the limited region he covered. However, as we had an entirely independent check through the dip and total intensity we were made quickly aware of some inherent defects due chiefly to the fact that a navigation compass already on hand had to be used. Thus in a heavy sea there would at times occur a lifting of the framework carrying the deflecting magnet and hence altering momentarily the deflection distance so that the shore constants would not then fit the observations. These mechanical defects have been entirely overcome in the new deflectors on the "Carnegie" and a higher degree of accuracy attained, though even with the defects named the instrument furnished results in the Pacific Ocean far superior to those scaled from the charts. So here again, owing to the care given to the control of the instrumental constants, useful results were obtained during the very period of experiment.

In the instrument on board the "Carnegie" the deflecting magnet is mounted *below* the card instead of above as was originally the case. The magnet may be easily placed at four invariable deflection distances. The construction has been improved in other respects by my assistants, Messrs. Fleming and Widmer.

DECLINATIONS.

While my attention was being devoted to perfection of appliances and methods for dip and intensity, my assistant, Mr. W. J. Peters, was making a special study of instruments for getting the magnetic declination at sea. Every known appliance was put to a practical test—they all were found subject more or less to the error arising from the motion of the card while the magnetic bearing of the celestial body was being taken. To eliminate this error it was necessary to extend the observations over a sufficiently long interval so that on the average it could be assumed that the various motions of the card had been eliminated. This had to be done more or less blindly, however, as one could never tell just at what point of the arc of motion the magnetic azimuth of the stellar body was obtained. Furthermore they all had movable parts subject to wear with frequent use, such as the axes of mirrors or of prisms and of the azimuth circle on the bowl. Likewise, graduation errors of the card had to be considered. The result of these defects was the introduction of "apparent" deviation corrections not due to the ship's magnetism but to purely instrumental causes. To be able to separate the "apparent" from the "true" deviations it was necessary to go through an elaborate series of shore observations whenever the vessel reached port. The ship instruments were invariably dismounted and used ashore alongside of the customary magnetic outfits for land work.

As a result, the "marine collimating compass" was devised by Messrs. Peters and Fleming and constructed with great skill and conscientious care by Mr. Adolf Widmer, chief instrument maker of the Department of Terrestrial Magnetism. Such an instrument is now in successful operation on the "Carnegie." No such attention, as far as known, has been given by any one else toward the perfection of declination work.

The basis of the instrument is a Ritchie standard 8-inch liquid compass with the card, however, removed, and an optical collimating system with scale introduced, enabling the observer to note the arc of motion of the magnet system *while sighting on the* sun or a star, hence knowing precisely to what part of the arc the stellar azimuth applies. In brief, practically the same method of observations can now be used at sea as on land, where the magnetometer circle would be set to some convenient point on the magnet scale and then scale readings taken of the positions of the magnet during the interval of observations. The angle is next determined between the circle setting and some mark, or the true meridian, and the declination is finally deduced. Similarly with the marine collimator compass. The angle (say, middle of scale) between the magnet and some celestial body, as the sun, is read with a pocket sextant to the nearest minute of arc at a given time, and then readings of magnet scale and of watch are taken. With the aid of the time readings, the motion of the sun during the interval of observation is taken into account, and the true azimuths determined, whereas the scale readings give the varying positions of the magnet system.

With this instrument, therefore, one is almost entirely independent of the yawing and rolling of the ship, making it possible still to get satisfactory results when with all other azimuth circle devices, hitherto used at sea, observations would be wholly impossible, or, at least, very uncertain.

In ten minutes a value of the magnetic declination may now be obtained possessing an accuracy attainable with previous instruments only by most careful observation and by laborious repetitions extending over a half hour or more to eliminate the motion of the card. Thus not only has the accuracy of declination at sea been increased, but, what is equally important, the time has been reduced and the possibility of getting useful results in all kinds of seas greatly extended.

METHODS AND FORMS.

Practical schemes for ocean observations to secure a desired result had to be devised and a number of printed forms prepared so as to simplify both the recording and the reducing of observations. But few hints could be gleaned from the reports of previous expeditions as to the best methods for determining the

* Terrestrial Magnetism and Atmospheric Electricity.

deviations, due to the ship itself, for all three elements. While considerable work has been done with regard to observations for declination deviations, comparatively little was there available for guidance in getting truly the dip and intensity deviations. It remains to be seen whether any other expedition has gone into these matters as fully as was done for the "Galilee." Fortunately this troublesome part of the ship work has been eliminated on the "Carnegie."

Suitable printed forms are a very great help not only in properly recording observations, but also in quickly calling attention to the omission of important information required by an office computer who, necessarily, is unacquainted with the circumstances under which the observations were made. A proper and suitable arranged record of observations helps much in the reduction of computation labor. It is interesting to note how even those who have not been accustomed to forms, and in fact "despise" them initially, when they once have gotten into the habit of using them, would thereafter not be without them.

PROMPT PUBLICATION OF RESULTS.

It has been my observation that there is nothing so harmful to magnetic research as lack of promptness in the reduction of the observational data and publication of the results. Delay in making the data available, with the opportunities afforded to-day, appears not only inexcusable, but frequently has caused to defeat the very purpose for which the observations were undertaken. Instances to prove this point might readily be cited.

To accomplish prompt reduction it is necessary to begin right, viz., to have instruments, methods of observation and those of computation, all form one harmonious whole and not be treated as though they were independent of one another. The instruments, as far as may be possible, should invariably be absolute ones, but relative ones, so as to permit a quick computation of absolute values. With instruments properly constructed and carefully tested it has been proved possible to get absolute values of the magnetic elements with an accuracy sufficing for all purposes—scientific as well as practical. To adopt then instruments and methods which make it impossible to communicate the results of observations until several years have elapsed, as is too frequently the practice, must be characterized as unscientific, to say the least.

Next, the observational methods must be such as to fit the purpose, the instruments, and the form of computation. It yet remains to be demonstrated that it is worth while, for a magnetic survey, to apply laboriously derived corrections due to diurnal variation, etc. My own experiences has been that in general, except for declination, this is labor thrown away and that the isomagnetic lines, which after all are but an adjustment of the entire field observations, would be the same whether the corrections are applied or not. The attempt should be made not to observe at every station at the same time, but at different times so that the corrections would be, more or less, of opposite signs for the various observation points.

In a project such as the magnetic survey of the earth, one could readily lose himself and spin out the survey so interminably that it would take nearer 50 years than 10 or 15 years—the time allotted to complete it—with no added advantage whatever. On the contrary, the application of secular variation corrections for a survey extending over 50 years would introduce far greater errors than due to the neglect of those spoken of especially when the provision is made to arrange the field work initially with the view of elimination of bothersome corrections as far as possible.

A good scheme of observation takes advantage of the capabilities of an instrument in the briefest possible time, and is so arranged that independent computers can get but one result, if no computation errors have been made. An observer ought never to forget that his observations have no value until they have been computed and, hence, he must bear the computer in mind and consider what his task will be. It is astonishing how such a simple truth as this is at times disregarded by observers. Having all these experiences in mind the work of the "Galilee" was arranged accordingly and still further has it been possible to put into actual practice these ideas on the "Carniegie."

Two days after the completion of the observational work at Falmouth, England, a summary of the magnetic results obtained on the "Carnegie" from Long Island Sound to Falmouth (September 1st-October 18th), embracing the three elements, were sent to the chief hydrographic offices issuing magnetic charts and important errors were pointed out. The summary was published in *Nature* ten days after the date of the last observation, and Gen. Rykatcheff presented the information before the Russian Geographic Society on October 27th.

At the date of writing I am in receipt of the reduced observations on the cruise from Falmouth to Funchal, Madeira, made nineteen days after the "Carnegie" arrived there. I know to-day the errors of the existing magnetic charts for this region—practically the same as covered by the Antarctic Expeditions of 1902-04, the "Discovery" and the "Gauss." The "Discovery" observations were recently published, but those of the "Gauss" have not yet come to my knowledge.

By the methods adopted it is possible for the director, in his office in Washington, to be almost as close in touch with the work as though he were continuously on the vessel himself. In brief, it may be said that the "Carnegie" is the most effective instrument of research in terrestrial magnetism thus far devised for mapping the earth's magnetic forces. With the present possible rate of progress on land as well as sea, we may confidently expect the completion of a general magnetic survey of the greater part of the earth by 1915.

The rapidity with which the present work is being accomplished naturally will raise the question in the minds of some as to its thoroughness; I may say the work is open to the inspection of any one at any time. Invitations have been extended to prominent scientific men to visit the "Carnegie" when in port, not only for the purpose of becoming acquainted with the instruments and the methods, but above all to give us the benefit of any criticisms or suggestions they may make.

FUNDS.

In a recent scientific article an author set forth fully the contributions of his own countrymen and then referred briefly to the magnetic work of the Carnegie Institution in a manner to imply as though its success and rapid progress was chiefly due to "ample funds." It did not appear to occur to him that possibly the funds have come because of the methods and principles followed from the very beginning of the work, and that if others were to adopt similar methods a corresponding success might be achieved by them. It has been my invariable custom never to undertake or advance anything that was not feasible and could not be presented and executed in a perfectly definite manner.

MISCELLANEOUS CONSIDERATIONS.

One of the first lessons to be learned in ocean work is that it is rarely, if ever, possible to have ideal conditions. In consequence the development of good judgment of the observer is one of the prime requisites. Sometimes in an instant he must be able to change his plan of observation and be content with a fair degree of accuracy or get no observations at all.

The chief outstanding difficulty, at present, is to get determinations of the magnetic declination when no celestial body is visible. In other words a device is desired which will furnish at sea an azimuth mark whose direction will be invariable within the desired degree of accuracy, during the intervals when celestial bodies are obscured. This device for best success must be as simple as possible and not be a source of disturbance to the magnetic instruments. The Anschütz-Kaempfe gyroscope compass does not, at present, appear to fulfill these requirements.

Fortunately, when over the deep seas, it is not necessary to observe the magnetic elements as often as on land, i. e., the distance from point to point of observation may be, if necessary, 200 to 300 miles. As a matter of fact every opportunity is embraced on the "Carnegie" to get a daily observation so that, on the average, the points are about 100-150 miles apart. If because of cloudy weather, declinations are missed for one or two days, it is not as serious as it would be on land, but still the opportunities of multiplying declination data, by some device, are exceedingly desirable.

Because of the introduction on the "Carnegie" of sheltering circular observation houses, in which most of the instruments are mounted, it is possible to get dips and intensities at any time, except, of course, when the sea is exceptionally rough.

I have said nothing as to the problems of organization and of administration, as it will be readily understood that these present peculiar difficulties in themselves when operations must be conducted over the whole earth.

Guiding Balloons by Automatic Wireless Signals

Two recent fatalities, apparently caused by the pilots of balloons losing their bearings, give fresh interest to Lutz's proposal to establish a series of small wireless stations, each of which will automatically emit a characteristic signal at regular intervals, day and night. These stations could be maintained most conveniently in connection with municipal electric light stations. The coast stations should have especially characteristic signals, in order to warn aeronauts of the proximity of the sea. The balloon

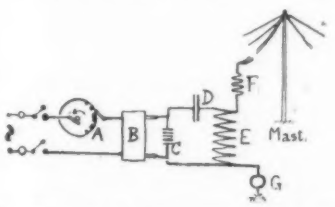


Fig. 1.—Diagram of Automatic Signal Station

would require only a light telephonic wireless receiver and an antenna formed of a suspended rope covered with copper lace. It has been proved by experiment that very good communication between a balloon and the earth can be maintained with such an apparatus, which costs very little and is not a source of danger to the balloon.

The automatic signal station (Fig. 1) requires no regular attendant, but only occasional inspection. The power required need not exceed one kilowatt, which would be employed during only a few seconds every hour or two. The requisite apparatus includes a rotary interrupter *A*, driven by clockwork or by a small electric motor, a transformer *B*, a spark gap *C*, an inductance coil *E*, an antenna wire F, and an ampere meter *G*. All of these parts can be constructed simply and cheaply, as they do not require continuous tuning and adjustment to varying conditions of service. The antenna can be supported by a mast or a chimney 100 to 150 feet high.

The receiving apparatus attached to the balloon can also be made simply and cheaply, as no lightning arrestor and little tuning are required. The detector, mica condenser and variable condenser can be in-

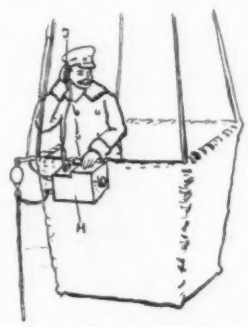


Fig. 2.—Balloon with Telephonic Wireless Receiving Apparatus

closed in a small wooden box *H* (Fig. 2) attached to the outside of the car. Nothing else is required except the hanging antenna and a telephone receiver *J*, but a 1,000-ohm rheostat for the estimation of the distance from the signal station may be included with advantage.

This description is taken from a note in *Prometheus*, the writer of which asserts that he has, on land, distinctly received signals emanating by a large wireless station more than 400 miles distant, with a receiving apparatus of this kind which cost about $10. An aeronaut provided with this apparatus could regard and keep his bearings by letting down the antenna, occasionally putting the telephone to his ear and estimating the distances of the automatic stations near which he drifts by the loudness of the signals heard. A more accurate estimate could be obtained with the aid of the rheostat.

Hydro-electric Energy from a Disused State Canal

THE *Electrical World and Engineer* recently gave an account of how an old canal, whose prosperity had been destroyed by the railway, is utilized by the Maumee Valley Electric Co., to supply a 62-foot head of hydraulic energy for electric generation purposes. The present power equipment comprises two 26-inch double-runner and one 26-inch single-runner waterwheels. The former machines are of the Allis-Chalmers horizontal type with side entry and center discharge, and each drives at 400 r.p.m., a 2,300-volt 60-cycle, 3-phase Allis-Chalmers alternator delivering 190 amperes per phase. The speed of these units is controlled by Allis-Chalmers type I oil-pressure governors, with oil pumps belted to the shafts. The 26-inch Leffel single-runner double-discharge turbine drives an alternator similar to the other machines but delivering 115 amperes per phase. This unit is controlled by a Lombard mechanical governor. The station supplies current at 13,200 volts to the city of Toledo, distant 8 miles.

Sympathetic Ink.—A dilute aqueous solution of ferro-cyanide of potassium (known as yellow prussiate of potash). To render it visible a solution of blue vitriol (brown writing) or green vitriol (blue writing) is used.

Electricity Meters

How Electric Current is Measured

ELECTRICAL energy is sold to consumers either by contract or at a charge proportional to the current consumed. In the latter case the current used by the customer is measured by a meter, similar in principle to a gas meter or water meter, on which the number of kilowatt-hours consumed is recorded by clockwork.

The most usual type of meter is the motor type, which may be described, in general terms, as a combination of fixed primary coils with a movable secondary coil, which rotates with a velocity proportional

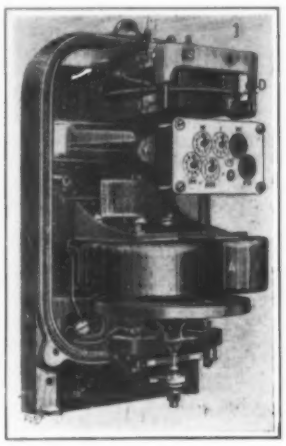


FIG. 1 THE THOMSON METER.

A, fixed coils; B, rotating coil; D, brake disks; F, brake magnet.

to the electric power consumed at the moment. The number of revolutions accomplished by the rotating coil is recorded by means of a clockwork which moves pointers over dials or shows the total number of revolutions, as in gas meters.

Meters are made of various capacities, from 1/5 kilowatt, corresponding approximately to the consumption of six lamps of 10 candle-power, up to 100 kilowatts and more. As the number of revolutions is proportional to the number of watts consumed, it is evident that a meter suitable for an installation of ten lamps could not be used for fifty or one hundred lamps, as the speed of rotation would be too great, and the mechanical parts of the meter would be injured. Furthermore, the electric part of the apparatus could not support an excessively strong current without damage. In general the meter is so constructed that it makes one revolution per second for the maximum current for which it is designed, and it is unwise to subject it to a greater load.

The following description of some of the electric meters which are most used in France is adapted from *La Nature*.

I. Meters of the motor type without iron cores.—The most generally used meters of this type are the Thomson and the Vulcan, which differ only by a few details of construction. Both are, virtually, ordinary electric motors with fixed primary and rotating secondary coils. Figs. 1 and 2 give general views of the two meters. An explanatory diagram of the Thomson meter is given in Fig. 4, 1. The secondary coil *B* of fine wire is wound on a very light frame, so that it will start with a very weak current. This coil is mounted on a shaft which turns in jeweled bearings, and it receives current from the brushes *b*. The fixed primary coils of coarse wire as designated by *AA*. The whole curent passes through these coils, while the rotating coil *B* is traversed by a derived current proportional to the voltage at the installation. The fine wire coil is thus subjected to an electromagnetic couple, due to the mutual action between the fixed and moving coils, and proportional to the product of the two currents, and, consequently, to the product of the total current used by the voltage by which that current is supplied. Hence the couple is proportional to the rate of consumption of electric energy.

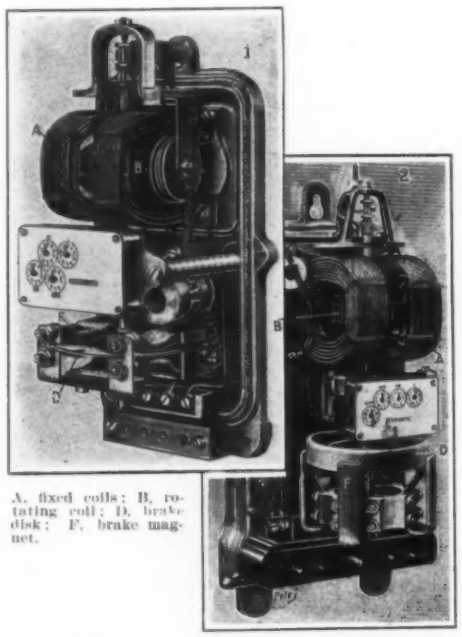
The motor starts as soon as any current passes through the coil; and as it carries no load it will tend to run wild. In order to regulate its speed, the shaft carries an aluminium or copper disk *D*, which rotates between the poles of a permanent magnet *F*. The induction between the magnet and the disk produces an opposing couple proportional to the velocity of rotation. The rotating coil, therefore, maintains a speed at which these two couples are in equilibrium. This speed is proportional to the motor couple, and therefore, to the power consumed.

Meters of this type can be used equally well on direct and alternating circuits. In practice various modifications of construction have been introduced. Particularly notable is the difference in the position of the fixed coils, in the latest model of the Thomson meter (Fig. 1) and in the Vulcan (Fig. 2). The arrangement of the Thomson meter makes the field of the fixed coils almost independent of terrestrial magnetism, while the construction of the Vulcan meter makes it necessary to set the plane of the fixed coils at the same inclination to the magnetic meridian in actual use that it occupied when the meter was standardized at the factory.

II. Constant voltage meters, or electro-magnetic meters.—The voltage of the distributing system is usually very regular. This fact allows the use of a type of meter for direct currents which is very much simpler than the Thomson meter. This is known as the O. K. meter (Fig. 3).

It is evident that if the voltage remains constant, it is necessary only to measure the strength of the current used. The electric power consumed can then be obtained by multiplying the current strength by a constant factor. This multiplication, furthermore, can be made by the meter itself, so that a meter designed for any particular voltage gives directly the number of kilowatt-hours consumed. In the O. K. meter a permanent magnet, which produces a constant magnetic field, replaces the movable fine wire coil which, in the Thomson meter, produced a field proportional to the voltage, while the fixed coarse wire coil, which produces a field proportional to the current strength, is retained. The permanent magnet (Fig. 5, 3) acts as an inductor and induces a current in the coarse wire coil which, in practice, receives only a very small portion of the current consumed, the remainder passing through a shunt. As soon as any current passes in the coil a couple is developed which causes the coil to rotate with a speed proportional to the current strength. This meter does not require any electromagnetic or other brake, because the electro-motive force developed in the rotating coil, and proportional to its velocity, tends to neutralize the already weak current coming from the shunt, so that there is no danger of running wild.

III. Meters of motor type with rotating fields, or induction meters.—These are applicable solely to alternating circuits. Several types are used in practice: The Cosine meter (Fig. 5, 1), the A. C. T. meter (Fig. 5, 2), etc. Their construction and operation are illustrated in Fig. 4, 2. The moving part is simply a disk of copper or aluminium which ro-



A, fixed coils; B, rotating coil; D, brake disk; F, brake magnet.

FIG. 2. THE VULCAN METER.

tates beneath the poles of two coils *AB*. The coil *A* is made of coarse wire, and carries the total working current. The fine wire coil *B* is traversed by a current proportional to the voltage, and is easily adjustable with respect to the coil *A*. Each coil produces a magnetic field which gives rise to induced currents in the disk.

The mutual action between these fields and the induced currents produces a motor couple. The theory of these magnetic fields is very complex, but it can be shown that the motor couple is proportional to the electric power consumed. A permanent magnet *F*, acting upon another portion of the disk, serves as a brake, by producing an opposing couple proportional to the velocity.

These meters are very simple in construction. The rotating part is extremely light, so that the apparatus is very strong and easily mounted. Meters of this type are very commonly used on alternating circuits.

In addition to the meters described above, there are

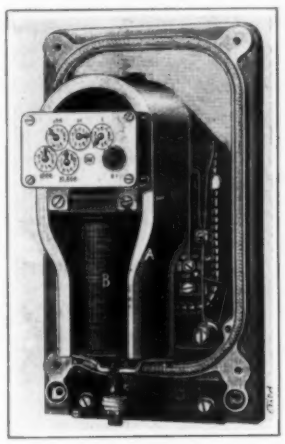


FIG. 3. THE O. K. METER.

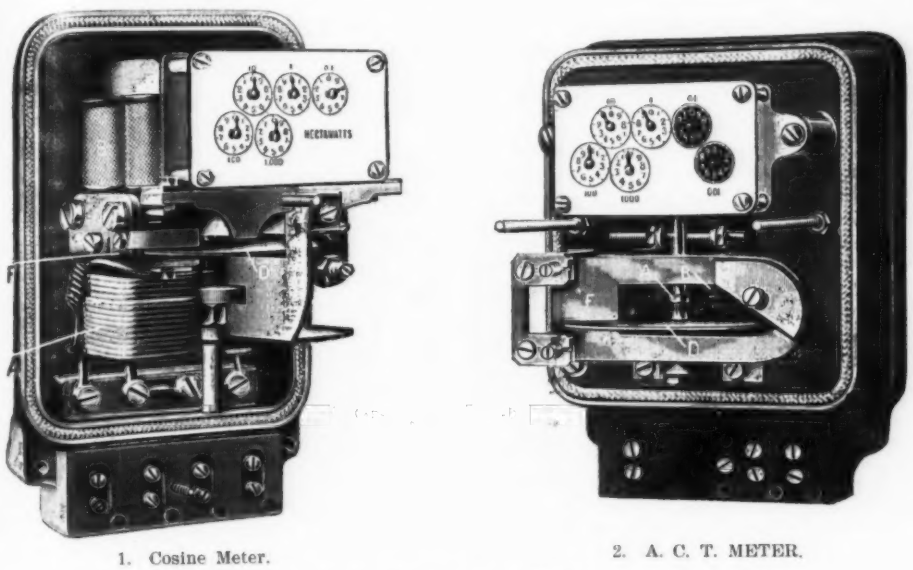
A, magnet; B, coil

several others, including the Aron pendulum meter, electrolytic meters, etc., but these are not largely used.

Conditions of Operation.—The electric meters described above are of very delicate construction, owing to the precision required of them and the comparatively low price at which they are furnished. The French syndicate of electrical power stations requires that the meter must start at 1/100 of its normal charge, and that its indications must be correct within 5 per cent for all values exceeding 1/20 of the normal charge. In practice these conditions are perfectly fulfilled, and the operation of the meters is quite satisfactory. In Paris, for example, where the municipal administration receives complaints from consumers of electricity, only thirty-two complaints, of which only three were found to have any just foundation, were received in 1908, when 55,000 electric meters were in service. Similar results have been obtained elsewhere. It may be asserted that the proportion of meters which balk does not exceed 2 per cent, and, in general, the meters which are found in need of repair or regulation mark too low and not too high. This is made evident by a consideration of the construction of the apparatus. The commonest causes of error are the invasion of dust, which increases friction, defects in the brushes and collectors, etc., all of which tend to retard the motion. The defects in collectors are especially noticeable in the Thomson and Vulcan meters, where there is a great difference of potential between the brushes, as the whole voltage is applied to the induced coil. In the O. K. meter the shunt circuit passing through the secondary is of so low voltage that this inconvenience is less marked. Induction meters give no trouble in this respect. The influence of temperature upon the magnetization of the brake magnet and on the resistance of the fine wire coil is easily corrected by compound winding of the primary.

It is interesting to compare the quantities of electric power consumed internally by the various meters. In the Thomson meter and in the induction meters the fine wire circuit, which is permanently bridged across the mains, occasions an expense of energy which is not negligible. A Thomson meter constructed for 110 volts consumes about 3 watts, or say 70 watt-hours in twenty-four hours. This consumption, entirely at the expense of the purveyor of electricity, as it is not registered by the meter, assumes considerable relative importance in the case of small consumers. This inconvenience does not exist in the O. K. meter, which has no fine wire circuit. This is one of the reasons which justify the employment of this apparatus for small consumers of direct current. On the other hand, the O. K. meter consumes considerable energy in the shunt, but only while the meter is in operation. This defect, added to the systematic error due to the erroneous assumption that the voltage is absolutely constant, has generally re-

stricted the employment of these meters to small consumers. The induction meter has a fine wire circuit, but the consumption when the meter is not in use is only about one-third of the Thomson meter. The induction meter is the strongest of all, and it is being generally introduced on alternating circuits of every kind. The induction meter is also the cheapest,



1. Cosine Meter. 2. A. C. T. METER.

A, coarse wire coil; B, fine wire coil; D, disk; F, brake magnet.

FIG. 4. INDUCTION METERS.

and costs one-fourth or one-fifth less than the Thomson meter, which is the next lowest in price.

The Use of Radio-active Substances in Therapeutics

PROF. WILHELM HIS, of the University of Berlin, recently made investigations on "The Treatment of Gout and Rheumatism by Radium," and these researches were founded by the consideration that radium, or at all events some of its derivatives, formed a constituent of certain natural curative springs, the action of which on gout and rheumatism is undoubted, though medical men have not been able to explain it satisfactorily. It soon became evident that both radium and radium emanation were capable of producing cures, which were especially remarkable in the case of gout and of the various rheumatic affections. The results obtained were reported by the Professor about a year ago to the German Balneological Society. Since then his experience has considerably extended.

The patients dealt with include 100 cases of chronic rheumatism and 28 of uric acid gout. Of the former, 47 were improved, 29 considerably improved, 5 nearly cured, while 19 were uninfluenced by the treatment. The most interesting of the cases were those in which limbs rendered useless by the disease were almost completely restored by the treatment, which was continued for periods of three months or longer. In gout, the results were much more striking. Twenty-eight patients were kept under treatment and under observation for a considerable period. Of these, 4 remained unaffected, while in 24 a marked improvement in the condition was achieved. Some of the patients have remained free from symptoms for a year after the termination of the treatment.

The most remarkable effect is noted in the behavior of the uric acid in the blood. Under the influence of radium emanation, the blood loses its uric acid within a few weeks. This was observed in 15 cases out of 18. On the other hand, the uric acid persisted in the blood of 3 patients even after a severe course of treatment. On two occasions actual deposits of uric acid under the skin of the ear (so-called "tophi") were seen to disappear during the treatment. The clinical improvement did not always run parallel with the uric acid content of the blood. Thus very marked improvement was obtained in a patient by energetic treatment, though the blood continued to contain uric acid. In another patient no uric acid was present in the blood either at the beginning or the end of the treatment, although he had gout nodules all over his body.

When water containing radium is drunk, part of the emanation is taken up in the inspired air, and another part is absorbed from the stomach and intestine. Emanation behaves like every other gas which is not a normal constituent of the body. It is excreted to a very slight extent through the kidneys, and to a large extent in the expired air. When the treatment is carried out by baths, absorption is only continued so long as the patient remains in the atmosphere laden with emanation from the bath water, and the foreign gas is excreted immediately. On the other hand, when carried out by means of drinking waters, the absorption takes place slowly from the intestine, and the body is being constantly supplied with fresh doses of emanation for three or four hours after a single dose. When the patient is given from three to five doses during the day emanation can be detected in the expired air at any period of the day.

Radium itself behaves in the body like other heavy metals; that is to say, it is absorbed slowly, and the absorbed quantity is excreted again through the intestine. So long as it is present in the body, small quantities of emanation are continuously developed from it. It is therefore clear that the most active application of emanation is achieved when the individual is breathing an atmosphere which contains a certain quantity of radium emanation. Under these conditions, an equilibrium will rapidly be established between the emanation content of the outer air and that of the blood. This equilibrium will be maintained so long as the body remains in this atmosphere. The emanation content of the blood will reach a level in this way which can only be attained by the drinking of exceptionally large quantities of water containing radium. Experiments have shown that it is usually sufficient for the purpose of obtaining definite curative results, and of ridding the blood of gouty patients of uric acid, to place the patient in an air containing from two to four "making units" per liter for two hours a day. "Emanators" have been constructed on this principle A stream of oxygen bubbles through a fluid containing a salt of radium and is saturated with emanation. The emanation issuing from the fluid is distributed equally in the air of the room by a ventilator. This method, however, has the disadvantage that it can only be applied when a special emanator is available. A portable inhalation apparatus has also been constructed.

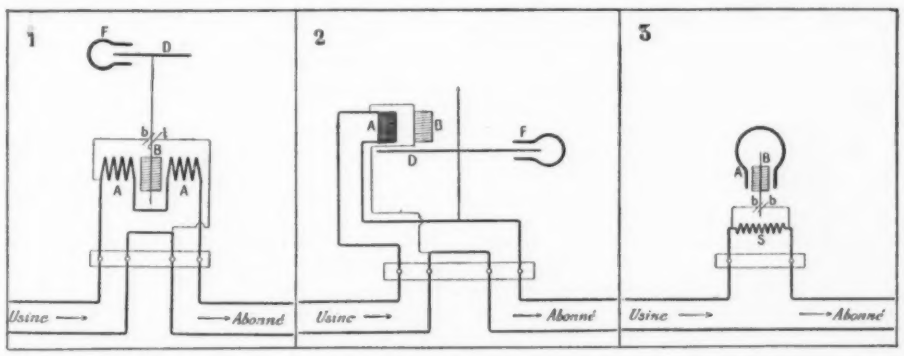
With regard to the mode of action of radium, the most important factor appears to be the property possessed by radium of rendering various ferments of the body more active than usual. This power of activizing ferments has been demonstrated in the case of pancreatin, pepsin, lactic acid ferment, diastatic ferments, and autolytic ferments. It is probable that the same is true of numerous other ferment actions in the body, though not for all; for example, it is known that the excretion of sugar by diabetic is not influenced by radium. In the case of gout, this property of radium can be demonstrated in a very clear manner. The disturbance in gout has been shown to depend on a slowing of the purin body metabolism, and not only is the formation and breaking down of uric acid slowed, but the mutual relations of the two processes are altered. In the gouty this is shown by the fact that, on a diet free from purin, though containing nucleic acid, the uric acid formed is not completely excreted within five days, as is the case in healthy persons. After prolonged treatment with emanation, however, the excretion takes place as promptly and completely as in a healthy individual. Gudzent was further able to show that uric acid and its salts are dissociated into carbon dioxide and ammonia under the influence of this action, and he demonstrated in a very ingenious manner that neither radium nor radium emanation produces this dissociation. It is due to radium D. Thus the actions that come into play in the treatment of gout by radium are very varied. In addition to the autolytic action, the action inhibiting inflammation, and that alleviating pain, there is a specific action on the uric acid and its salts, and on the processes regulating the quantity of uric acid in the body.

Another radio-active substance—mesothorium—has been prepared in considerable quantities by Dr. Otto Hahn. As compared with radium, the want of durability of this preparation is amply compensated by the greater ease with which it can be obtained from raw material. It is more than probable that other radio-active substances will be discovered, and will bring the treatment of gout and allied complaints by radio-active substances within the reach of all. A great deal of experiment and observation is still required, more particularly to make sure that no evil results may appear side by side with the undoubted benefit which has already been obtained.—*Nature.*

Automatic Alternating-current Block Signal System for Steam Railroads

IN the *Engineering News* J. W. Lee described what are probably the first automatic signals on a steam railroad with alternating current for operating and lighting the signals, as well as for supplying the track circuits. These signals were installed on the Cumberland Valley Railroad, between Lemoyne and Mechanicsburg, Pa., a distance of 7 miles, in 1908, and they have just recently been put in regular service. Power is supplied from a 2,200-volt, 25-cycle, single-phase line carried on poles along the right-of-way, current being obtained from the United Electric Company at Lemoyne. Lightning arresters are placed at intervals of 2 miles, and trouble from lightning has been confined particularly to an occasional fuse blown out.

The small amount of energy used by the 2-candle-power lamps to light the signal does not justify putting them out in the daytime, and the use of electric lights not only avoids the expense of maintaining oil lights, but gives better service in that there is no smoking of lamps and lenses, and light-failures are reduced to a minimum. Transformers are used with suitable taps to step down from 2,200 to 55 volts for operating the signal motor and lights, and 5 volts for track circuits controlled by suitable resistances. The motors are of the induction type, and have no con-



1. Thomson Meter. 2. Induction Meter. 3. O. K. Meter.

A, coarse wire coils; B, fine wire coil; D, brake disk; F, brake magnet.

A, coarse wire coil; B, fine wire coil; D, motor disk; F, brake magnet.

A, magnet; B, coil; *bb*, brushes; S, shunt.

FIG. 5. DIAGRAMS OF ELECTRIC METERS.

tacts or brushes and no friction surfaces aside from the two armature bearings. The third, or clear, position of the signals is controlled without the use of line wires, so that the two main wires are the only line wires used in the automatic territory. Track circuits average 1 mile, with longest circuit 7,000 feet. No batteries are used on any part of the automatic signal system, and the maintenance expense is limited chiefly to the proper lubrication of the signal mechanism, and the care of the rail bonds and insulated joints.

The signals have three positions in the upper right-hand quadrant, normally clear. The operation of automatic block signals of the three-position, upper-

quadrant type is as follows: If the line is clear ahead of a train, the signal blades will normally stand in a vertical position indicated by a white light at night, with a red marker light 7 feet below it and 2 feet to the left of it, giving it a staggered effect, indicating that it is an automatic signal. If a train occupies the block immediately in advance of a signal the blade or arm will assume a horizontal or stop position, indicated by a red light at night; the following train will come to a full stop at the signal and then proceed carefully, expecting to find a train ahead. If a train approaching the signal finds the blade in the 45-degree position, indicated by a green light at night, it shows that the block immediately in advance is clear, but that the second block ahead is occupied. Under this arrangement, a train approaching a signal showing a white light is assured of two clear blocks, or, in other words, the track is clear for 2 miles ahead.

Recent Bridge Construction in America*

Some Observations on Modern Tendencies

By Henry S. Jacoby, Professor of Bridge Engineering at Cornell University

It is surprising to notice how few railroad bridge trusses with pin connections are being built at present. This tendency is not merely due to the decreased cost of foundations and piers or abutments due to the extensive use of concrete which makes the economic span shorter than formerly, but wherever an old pin span can be divided by an intermediate pier without excessive cost, two riveted truss spans or two plate-girder spans will replace it. The length of riveted trusses has been steadily increasing as the shops have changed their equipment and methods so that the maximum span has passed 400 feet, and spans between 200 and 300 feet are numerous. Accordingly, pin spans are mainly confined on railroads to crossings of the larger rivers where the interests of navigation require long spans.

The longest riveted truss spans in the United States are those of the new terminal bridge over the Missouri River at Kansas City, the span being 425 feet and 6⅛ inches. The special reason for making this a riveted truss bridge is that one of the spans has a suspended lifting deck in which the stiff suspenders telescope into the hollow posts of the truss. The upper deck accommodates the highway and electric railway traffic, and the lower deck the railroad traffic. The bridge has such an elevation that deck trusses are used over the river in all spans except that of the lift bridge. Since structural reasons required the through trusses of the lift span to be made with riveted connections the same details were used for the fixed spans to secure uniformity.

In the United States the riveted trusses that are next in length to those mentioned in the preceding paragraph, are located in the channel spans of the Sixth Street Viaduct over the Kaw River at Kansas City. The trusses are also of the Baltimore type, with a span of 300 feet, 10 inches. Next in order come the riveted truss spans of the Idaho & Washington Northern Railroad over the Pend Oreille River at Box Canyon, Idaho, completed in 1910. The channel span is 280 feet and was erected from one end by the cantilever method without the use of falseworks. The adjacent shorter span was used for this purpose as an anchor span.

In Canada the largest riveted truss bridge for railroad traffic has an effective span of 412 feet 8 inches. It is on the Canadian Pacific Railway, where it crosses the French River, 43 miles south of Romford, Ontario. Special conditions also led to the adoption of this unusually long span for riveted trusses. The Cisco bridge over the Fraser River in British Columbia, erected in 1910 on the same railroad, has riveted trusses with a span of 315 feet, which are designed for E50 loading.

It is worthy of note that the longest span of a pin truss railroad bridge remains the same to-day as in 1893, or 546.5 feet. Only one light highway bridge exceeds this in effective span, with a length of 586 feet. At present, however, the sub-structure is well advanced for the new Municipal bridge at St. Louis, popularly known as the "free bridge," in which the effective spans are 668 feet, due to the demands of navigation as decided by the United States government. This bridge is to accommodate the highway on an upper deck and a double-track railroad on the lower deck. It is to be built of nickel steel and it is proposed to begin the erection this spring.

Plans are under consideration which make it probable that in a few years the largest span for simple truss bridge will exceed 700 feet.

The larger live loads now adopted by some railroads tend to increase still further the magnitude of plate-girder construction. The construction of bridges now in progress on the Boston & Albany Railroad for E60 loading includes a plate girder for a skew span with solid floor which has an effective span of 115 feet and a gross flange section of 249.5 square inches exclusive of the equivalent flange area of the web.

There are at least two other railroads both of recent construction in which all the bridges are designed for E60 loading, the Virginian and the Carolina, Clinchfield & Ohio. They were built primarily for the economic transportation of coal, requiring very costly construction in order to secure the low grades adopted.

A number of prominent bridges are being replaced or reconstructed. The Lachine bridge over the St. Lawrence River near Montreal is to be changed from a single-track to a double-track bridge using only simple trusses, thus causing the only statically indeterminate continuous truss bridge in the country to disappear. During the past season work was begun in lengthening the piers and in building some additional piers. After completing a new single-track bridge alongside of the present trusses on the longer piers, the old structure will be removed, many of the spans being used elsewhere on branch lines, and a new single-track structure built to replace it.

The Fraser River cantilever bridge on the Canadian Pacific Railway near Cisco in British Columbia, completed in 1884, was removed last year and will be re-erected on Vancouver Island on the Esquimalt & Nanaimo Railroad, one of the operated lines of the Canadian Pacific. The Cisco bridge was replaced by three simple truss spans. The middle one with a span of 315 feet was erected by the cantilever method, using the side spans as temporary anchor spans. All of the trusses have riveted connections.

The superstructure of the Coteau bridge over the St. Lawrence River was also reconstructed last year by the Grand Trunk Railway by substituting heavier riveted trusses designed for modern loading. The trusses were built on skids on an island, and between trains one of the old spans was removed by floating it out on a barge, and a new span put in its place by the same method. One of the most interesting features of the design consists in the complete elimination of all lacing in the web members of the trusses, exclusive of the end posts. The difference in appearance due to this feature is apparent to an observer at a considerable distance. The web members are composed of two pairs of bulb angles connected by a solid web plate. This gives an H-section with a bulb at each corner of the post, thus securing greater resistance to injury in the shops, during transportation, and in erection. In some cases the section is increased by adding two plates on the outside. The value of the bulb angle in ship building has long been recognized, but it appears that the value of this detail of bridge construction in Canada has not been recognized in the United States. It is claimed that it has been used in Canada for a number of years with entire satisfaction.

An item of bridge history worth noting is the fact that in 1909 the Grand Trunk Railway replaced a deck tubular bridge which had been in continuous service since 1855. The excellent quality of the material and workmanship is attested by such long service under steadily increasing live loads.

The old chain suspension bridge over the Merrimac River between Newburyport and Amesbury, Mass., built in 1810 and strengthened for electric car service in 1900, was replaced last year by an entirely new suspension bridge of modern design. Because of their historic associations it was at first proposed to suspend the old iron link cables alongside of the new wire cables, but this plan was abandoned for fear of detracting from the handsome appearance of the new structure.

The first cantilever bridge in this country was located on the Cincinnati Southern Railroad (now a part of the Queen and Crescent route) across the Kentucky River, and was completed in 1877. At that time it was also the highest bridge in the United States. This bridge was replaced in 1910 by three simple truss spans of the same length of 375 feet. The deck of the new bridge is 31.3 feet higher than the old one in order to improve the railroad grade. The trusses were erected by the balanced cantilever method from each tower, and without interference with traffic.

A new cantilever bridge for highway traffic has recently been built over the Ohio River at Sewickley, Pa. The anchor spans are 300 feet long and the cantilever span 750 feet.

A large steel arch bridge is being erected at present over the St. Croix River seven miles north of Stillwater, Minn., on the Minneapolis, St. Paul & Sault Saint Marie Railroad known as the "Soo line." It consists of five arch spans of 350 feet each, exclusive of the viaduct approaches. The arches contain one particularly novel feature in design, by means of which the arches have practically three hinges for dead load and temperature, and two hinges for live load. The bridge is 150 feet high.

Work has been begun on another important three-hinged spandrel-braced arch bridge over the Crooked River in Oregon, for the Oregon Trunk Railway. Its span is 340 feet. This railroad is to connect with the Spokane, Portland & Seattle Railway at the Falls of the Columbia River at Celilo by means of a bridge with simple truss spans, which is now under construction.

A number of direct lift bridges have been built in the last two years and others are now under construction, thus indicating a considerable revival of the type of the South Halstead Street bridge in Chicago, completed in 1894. Previous to that time the type in which a simple span is lifted vertically with the aid of counterweights had only been used for very short spans like those over the Erie Canal.

One span of this type is in the new Mississippi River bridge at Keithsburg, Ill., on the Iowa Central Railway. The span is about 230 feet and the lift about 45 feet. The inclined legs of the towers are connected to the adjacent fixed span, and in case the river channel shifts the towers may be transferred and another span arranged to lift. Another one completed last year is the Hawthorne Avenue bridge at Portland, Ore., which has a lift span about 244 feet long. The width of this highway bridge is 63 feet 8 inches, and the vertical lift is 110 feet.

Reference has been made previously to the lifting suspended deck of one of the spans in the Kansas City bridge which gives a clearance of 55 feet for steamboats. At Portland a bridge is under construction in which a suspended deck is to be lifted for vessels requiring a low clearance while the entire span is lifted for higher clearances. At Chicago the direct lift has been adopted for a skew span on the Pennsylvania lines. The span is about 217 feet between centers of bearings and the vertical lift about 130 feet. Several other examples of this type are located in Arkansas, Idaho, and Washington, and during the past year one was completed at Mohawk Place in Cincinnati over the Miami and Erie Canal.

Bascule bridges are being built extensively, and their use is no longer confined to locations where it is necessary to avoid encroachment upon the adjacent frontage for docks. They seem to enjoy the especial favor of the operating departments of the railroads.

A large number of reinforced concrete arch bridges are being built throughout the country both for railroad and highway purposes. The bridge over Rocky River near Cleveland which has the longest clear span in America, or 280 feet, was completed last year. The smaller spans of the large bridge at Spokane are doubtless completed by this time. Work on the 281-foot span was delayed on account of the accident to the centering, and in order to avoid dangers due to high water it was proposed to build the new centering on top of a steel truss bridge designed for another location but temporarily used for this purpose.

The bridge of the Boston Elevated Railway over the Charles River at Boston and Cambridge is unique in being the first one in which two hinges are employed. Two separate ribs are used in each span which support reinforced concrete floor beams. The stringers consist of steel I-beams on which the ordinary type of open bridge floor is laid, while between the two tracks and outside of them there is a concrete slab floor.

The spandrel walls cover the entire area above the arch ribs between the supporting pillars of the floor beams, but they are made hollow and as light as possible since they are not intended to carry any live load. Being adjacent to the Charles River dam, special attention was given to the architectural treatment so as to give it the appearance of a monumental structure.

An interesting feature in its construction was the use of an electric locomotive to haul the cars to carry concrete from the elevator at the mixer to the various places on the bridge where it was deposited through chutes.

A bridge which deserves special mention is that completed in 1910 over the Colorado River at Austin, Texas. Its total length is about 1,000 feet, and it has

* Abstracted from an article in *The Cornell Civil Engineer*.

eight equal arch spans. The bridge is very simple in design, but of excellent form and proportions, while the overhanging sidewalks and its supporting brackets give that distribution of light and shadow which adds so much to the beautiful appearance of the structure.

Another concrete arch bridge of importance is being built on Kings-highway in the city of St. Louis. The three large spans are 140, 170, and 140 feet, respectively. On account of the character of the foundation bed it was necessary to adopt an unusual construction to spread the load over a large bearing area by means of reinforced footing slabs, and vertical partitions and sidewalks forming a kind of cellular construction.

More than thirty concrete structures are included in the Hopatcong cut-off east of the Delaware Water Gap on the Delaware, Lackawanna & Western Railroad which has been under construction for some time. Among these are two very large arch bridges, the one over the Delaware River being 1,450 feet long and containing more yardage of concrete than any other concrete bridge in the country. It has five spans of 150 feet in the clear, and two spans of 120 feet, besides several smaller approach spans. The Paulins Kill bridge not far distant is 1,100 feet long, but on account of its greater height and favorable location presents a more impressive appearance than the other.

In many cases the single arch culverts accommodate a highway and waterway in the same structure, the waterway being placed beneath the floor of the highway, in one or two culverts of rectangular cross section. On account of the high fills these structures are sometimes over 300 feet long, giving the appearance of a short tunnel. All of these concrete structures give the impression of being excellent in the character of their construction as well as in design, and this quality will undoubtedly have a good influence on future construction, because of the very large number of engineers and contractors who have visited the work on the cut-off.

The preliminary investigations in regard to foundations were so thorough that it was not necessary to revise the plans of structures after the required excavations were made. This feature deserves especial mention because it is frequently not given adequate attention, and in that case it either leads to a considerable increase in subsequent cost of the structure above what it would have been if the true conditions had been known before the design was first made, or it places extra burdens upon the contractor for which he is not fairly responsible.

Considerable increase is noticeable in the construction of reinforced concrete slabs supported by concrete pile bents thus forming a trestle on which the regular ballast and tracks are carried. There are many localities where a low trestle must be used in order to avoid restricting the openings for flood waters. At certain intervals a concrete pier is substituted for a pile bent in order to give additional resistance to longitudinal traction. The Chicago, Burlington & Quincy Railroad has been a pioneer in this type of construction, the Chicago, Milwaukee & St. Paul, Rock Island, Northern Pacific and other western railroads either have built similar structures or have adopted plans for future construction. The reinforced concrete slab for short openings has been adopted as standard on a large number of the leading railroads of the country. The track elevation of the Chicago, Milwaukee & St. Paul Railroad in Evanston is notable for its successful application of the slab and ballast deck with intermediate supports on beams and columns on the lines of the curb at street crossings.

The same railroad has made the most extensive development of the hollow abutment. The form most frequently used is the reinforced U-abutment with arched openings on the sides and slab top, the sides being merely curtain walls to support the slabs. The retaining wall feature is largely eliminated. In the more advanced form arched openings are run in both directions, leaving heavily reinforced pillars or columns to support a part of the slab floor.

The largest reinforced concrete beam which has probably been built in this country was observed last November under construction at Tacoma, Wash., where N. Twenty-third Street crosses Buckley Gulch. The viaduct has seven spans, of which the largest is about 68½ feet. Two beams carry a total width of roadway and sidewalks of 42 feet and the floor beams are spaced a little over 7½ feet between centers. The beams in the long span are 6 feet wide and 10 feet deep. A detailed description of this design will doubtless be prepared for publication in due time by the consulting engineers, for the engineering profession must be interested in the design and construction involving beams of such magnitude. Their observation under traffic ought to furnish important information as a guide for future designs.

The use of concrete piles for the foundations of both bridges and buildings is extending very rapidly. Most of those now in service are of patented forms in which the pile is cast in place after a hole is formed by means of a steel core or a hollow pipe fitted with a point. Frequently the opening is lined with sheet iron to maintain its shape until the concrete is deposited.

In the other class employed the piles are molded in forms and reinforced by longitudinal bars which are tied together at intervals by wire. These piles are driven like timber piles with the aid of the water jet and hammer. Some of the designs are also patented while others are not. On railroad construction at least the piles which are molded and driven after seasoning are regarded with increasing favor.

A new development in foundation work consists in building open caissons of reinforced concrete instead of timber or steel. At Black Rock on Niagara River a caisson of this character was successfully sunk in 1910 through 50 feet of very tough red clay to the rock bottom. The frictional resistance was found to be greater than that heretofore recorded either with or without the pneumatic method of sinking. The caisson was sunk for the pivot pier of the new swing span of the Grand Trunk Railroad bridge, necessitated by the construction of the new lock and canal built by the United States.

At Portland, Ore., caissons of a similar type were used for two bridges over the Willamette River, one for the Hawthorne Avenue highway bridge, and the other for the bridge of the Oregon Railroad and Navigation Co., which also accommodates highway traffic. These foundations had to be sunk to a depth of about 120 feet.

The great advantage in using concrete in these caissons is that when the sinking is completed and the interior is then filled up with concrete the walls and partitions of the caisson become a permanent part of the substructure.

The use of reinforced concrete in the roof of pneumatic caissons has reduced the amount of timber very materially, and correspondingly reduced the compressibility of the roof when the pier and its load are supported. In the caissons of the McKinley and Municipal bridges at St. Louis the timber in the roof of the air chamber consists of one layer of 12 by 12-inch and 14-inch timbers respectively, and a lining of 3-inch plank.

The progress in pneumatic foundations during the past forty years is shown by comparing the construction of the foundations for the Municipal bridge in 1910 with those of the Eads or St. Louis bridge, and in which the depths are nearly the same. The total time, including delays, was cut down over 50 per cent, the loss of human life due to caisson disease was reduced to but a small fraction of that entailed in the old structure, while the cost of the substructure per cubic yard has been reduced about 70 per cent.

As another illustration of the use of reinforced concrete in substructures, reference may be made to the protection pier of a swing bridge over Red River at Alexandria, La., on the Missouri Pacific Railway system. So far as the writer knows this is the first time that a protection pier has been built of this practically permanent material.

The use of reinforced concrete in building construction is steadily advancing. The value of a rigid building in reducing the cost of maintenance of machinery is becoming more evident with increasing experience. In one six-story building where considerable machinery is employed the cost of maintenance is several thousand dollars a year less than in the old structure with its floor vibrating under the machines. In another case where the operatives experienced serious fatigue due to vibration in the old building, they find considerable relief since the presses are installed in the new concrete building.

In a new concrete building on pile foundations used for a flour mill, a series of gyrators weighing four tons each on the fourth floor when rotating 150 times per minute produce scarcely a tremor. When the machinery was once lined up true it remained in that condition.

It is interesting to notice the character of the floor construction in office and mercantile buildings. In Greater New York the beam and slab construction is used almost exclusively, if not entirely so. In Boston only about half of the floors are of that form, while the flat ceiling is used for the balance. In some of the narrower buildings only transverse beams about ten feet apart are used, thus interfering less with lighting from the two sides. In St. Paul and Minneapolis the flat ceiling or mushroom construction predominates in a large degree. In Chicago and St. Louis a third form is being introduced in which the beams are shallow and about four feet wide, running in both directions giving the effect of a paneled ceiling. In Seattle the flat ceiling is used only to a limited extent.

In the tall steel buildings the reinforced concrete slab floor seems to be used in the majority of cases, the slabs being supported by encased steel beams. In some of the lower office buildings steel columns are used, with enough steel in the form of horizontal bracing for the steel frame as well as for the reinforcement of the concrete beams. Such steel bracing may take the form of two pairs of angles laced. They are strong enough as beams to support the forms for the concrete beams which envelope them, as well as the floor slabs.

It may be of interest to call attention to the severe test applied by the forces of nature to the reinforced concrete arches of Long Key Viaduct on the Florida East Coast Railroad. The arches are full centered and have a span of 60 feet. The top of the spandrel walls is about 30 feet above mean sea level. Since its construction the viaduct has been subjected to the combined action of wind and waves in the hurricanes of 1909 and 1910. The ocean waves broke over the top and cut out the track filling, but the concrete arches withstood the fury of the storm practically uninjured.

It is always interesting to find an engineer who is a master in the design of simple structures, especially when the material used is timber. It is unfortunate that so many engineers have regarded the design of many of the details of timber structures as unworthy of their serious study and have turned them over to the master carpenter for solution. For this reason the development of timber design has been materially retarded, while modern conditions have not been adequately met.

In Seattle, the plans were seen of an auditorium in which all the timbers of the roof trusses were connected at the joints by spikes or nails except at the end joint, where a casting and bolts were used. Since the structure was intended for temporary use, this method of framing was especially appropriate. The engineer made the design of every detail, however, the plans show the location and size of every spike, with proper spacing and relation to the grain of the wood, and a knowledge of the strength of nails based upon experimental investigation. It is readily appreciated that this method gives cheap and rapid construction.

The same engineer used the same simple details in the design of a truss span, which, in connection with a trestle, was required for construction purposes at a power plant. The bridge had to be built across a deep gorge where falsework could not be used, and the only means of crossing the gorge was a suspension foot bridge that would permit one man to carry one plank across at a time. These unusual conditions were met by using planks and spiked joints in building each half of the truss, and of its connection to a counterweight consisting of a box of sand, then rolling it out on the bank until the projecting cantilevers could be united at the middle. The central span consisted of ten panels, each sixteen feet long, and was designed to carry an electric locomotive and dump cars.

A number of evidences were found of a tendency to develop a more rational type of contract for construction. In the ordinary form of contract the usual tendency is to place the whole burden of responsibility upon the contractor even if there are many uncertain elements due to lack of information. In many cases the owner and his engineer omit to make the previous investigations regarding actual conditions affecting foundations or other details, and as a result there is an element of gambling in the contractor's bid. Sometimes the engineer does not even assume full responsibility for his own plans.

As an illustration of a new and equitable method of payment, the contractor is to be paid for the actual cost of labor and material, plus a given percentage for the use of his equipment and organization, including profit, plus a bonus consisting of a certain percentage of what he can save below an approved estimate of cost, minus a penalty consisting of a corresponding percentage of any excess of cost over the estimate. Such a contract makes it to the interest of both parties to cooperate in advancing the work, and it furnishes an incentive to the contractor to maintain or improve the efficiency of his organization.

Another element of progress which is apparent as one observes new construction throughout the country, is the increased attention given to a systematic arrangement of the work. This is particularly noticeable in reinforced concrete building construction, and the remarkable speed with which good work of this kind is done to-day is largely due to an orderly arrangement of the work of the different groups of men engaged in the erection of forms for columns, beams and slabs, placing reinforcement, depositing concrete, and the many other operations incident to the handling of the material and placing it in position, without interfering with one another.

It is very instructive to see the careful analyses of cost for both material and workmanship which are made by some of the leading contracting engineers for buildings under construction, by means of which it is possible to prepare fairly accurate estimates of

buildings of different forms and subject to various conditions. The number of elements considered at present in this connection is very much greater than was regarded necessary some years ago. There are bills of material for the time keeper, superintendent, and the purchasing department; costs of material and of labor, divided by stories in the building; columns, beams, windows, and other details are all numbered according to a simple plan, so that every item can be located promptly. There are preliminary estimates to answer the first questions that arise when a project is under consideration; official estimates for the tender of bids; and final statements of cost, and a discussion of the variations between them that may be of service in future work.

Application of Geared Steam Turbine to Rolling Mill Driving

IN a paper read before the West of Scotland Iron and Steel Institute, A. Q. Carnegie described a three-high steel plate rolling mill, with rolls 28 inches in diameter by 84 inches long, to which a Parsons steam turbine with 2-step helical gearing has been applied. The mill is erected at the Calderbank steel works of J. Dunlop & Co., and runs at 70 revolutions per minute, the turbine speed being 2,000 and that of the intermediate shaft of the gearing system being 375 revolutions per minute. The high-speed pinion is of chrome-nickel steel, forged solid with its shaft, 7.143 inches diameter at pitch line. It has 25 teeth 3½ inches diametrical pitch. The wheel into which it gears has 131 teeth, is 37.429 inches in diameter and 24 inches face width. The second gear has a mild steel forged pinion with 23 teeth 2 inches circular pitch, diameter at pitch line 14.912 inches, gearing into wheel 80.848 inches in diameter with 127 teeth. The face width of this gear is 16 inches. The double helical teeth are at an angle of 23 degrees. The turbine is designed to run either with exhaust steam at 16 pounds per square inch absolute, or with live steam at 60 pounds per square inch above atmospheric. There are two steam inlets, one at the high-pressure end and the other about the center of the cylinder, each having a steam chest and double-heat balanced throttle valve and independent emergency trip valve. The blade areas are proportioned so that when working at full load with exhaust steam there is atmospheric pressure at the first row of low-pressure blades and the high-pressure blades are running idly in steam of that pressure. When the whole load is taken over by high-pressure steam the pressure at first row of low-pressure blades falls to about 8 pounds absolute. The condenser is of the usual Parsons type and has a vacuum augmenter; the air-pumps being motor-driven and of Parsons' compound type. The power available from the turbine is 750 brake horse-power. The fly-wheel with its shaft weighs nearly 100 tons. The external diameter of the wheel is 23 feet, and the stored energy in this flywheel is about twenty times that of the turbine and gears, so that only a small fraction of the shock reaches these. The lubrication of bearings is by oil under a pressure of 8 to 10 pounds per square inch from a pump driven from an extension of the governor shaft, and the gearing is lubricated by another oil-pump which draws oil from settling chambers and sprays it on to the teeth.

Recent Development of Modern Gas Power Plants in the United States

IN a recent bulletin of the Bureau of Mines, some interesting facts are given by R. H. Fernald, on American producer gas developments. The fuel-testing plant of the U. S. Geological Survey has been at work since 1904, and various bituminous coals, lignites, and peats from twenty-six different States have been tested and compared as to suitability in both steam and gas-producer plants. Previous papers have given some results of this work, but in this official bulletin all the tests are detailed with reference to kind of coal and results of firing, to quantity and quality of gas yielded, and to the comparative consumption of fuel for steam and for gas-driving per e.h.p.-hour. The average ratio of coal as fired per b.h.p.-hour under boiler to coal as fired per b.h.p.-hour in gas producer was 2.7, and in some cases coal which was quite useless for steam-raising gave a good result in the producer. The views of manufacturers of producer-gas power plants in the United States were obtained by questions addressed to them in 1906 and in May, 1909, and the difficulties in the way of the spread of the system as given in 1909 are taken up *seriatim* and at length. The views of owners and of operators of producer-gas plants throughout the country have also been inquired into, and a bulky table and two maps show the various installations throughout the country. Plate I is based upon the number of plants in each locality, and Plate II on the relative capacity expressed as horse-power. The list of installations, which occupies fourteen pages, does not include every one in the States. Some European examples are quoted to show the benefits arising from an advantageous situation for the power plant, and the favorable conditions in the United States are then pointed out. A list of all the official publications on fuel-testing is given.

The Sanders Teacher

No ordinary obstacles are those that must be faced in learning the newest of all arts, the conquest of the air. Any device that lessens the risk to life and property which inevitably attends the efforts of the novice must be hailed with welcome.

We reproduce from *Flight* some illustrations and

FIG. 1.—THE SANDERS TEACHER IN USE

a description written by D. M. Haward of an accessory designed to meet these requirements.

"Even the most apt pupil is certain to find himself in difficulties at some time or another during his probation, and owing to lack of skill the machine is necessarily sacrificed to save his life, or at least to prevent a serious accident. The invention, therefore, of a device which will enable the novice to obtain a clear conception of the workings of the control of an aeroplane, and of the conditions existent in the air, without any risk personally or otherwise, is to be welcomed without a doubt. Several have already been constructed to this end, and the Sanders Teacher is the latest to enter the field.

The aim and object of an invention of this kind is naturally to render tuition safe to the pupil while at the same time giving him confidence. Now there is a tendency to design such an apparatus merely for purposes of balance and without any real resemblance to an actual aeroplane, while the very balance is so exaggerated that the pupil is placed under conditions that are in no way so arduous in free flight.

"The Sanders Teacher seeks to overcome both these difficulties. In the first place the teacher so closely adheres to the construction of the actual aeroplane that the pupil in learning to control it is simultaneously learning the control of the machine he wishes to pilot, and the principle is applicable to any make or type of aeroplane. In the second place the balance of the teacher is so arranged on scientific principles that the conditions are practically the same as if the pupil were actually in the air. The varying force of the wind has effect in almost an identical manner as on a working aeroplane, while the niceties of lateral and longitudinal stability are not carried to an extreme.

"The device, as will be realized from the description following, is neither costly nor elaborate, while

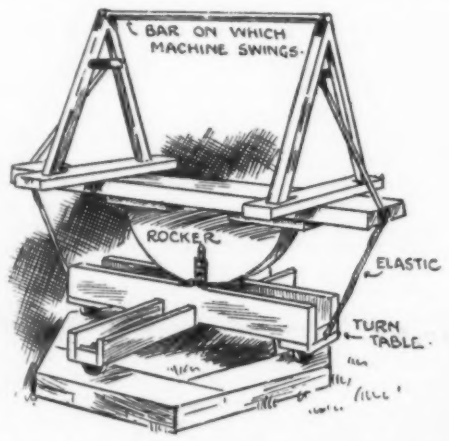


FIG. 2.—THE SANDERS TEACHER. THE PIVOTED ROCKER

the perfection of workmanship to be found in the Sanders biplane is also plainly noticeable here.

"The machine consists of a fuselage elevator, two lateral ailerons and a rudder either single or double planed. The control is a simple motor steering wheel in front of the pupil connected up with elevator, rudder and ailerons. All these details are standard parts of the Sanders biplane and can be substituted if desired by the same part of any other type of aeroplane. Thus, the purchaser of a Teacher is buying parts which can be used later if he wishes in the construction of a machine, and his outlay can therefore scarcely be considered an extravagant one. The fuselage is slung on to a wooden pivot consisting of a hexagonal bottom on which a crossway square running on wheels is placed. Above this is a rocker bearing a flat board surmounted by two triangular brackets with a bar running through sockets at the top. This bar also passes through two corresponding sockets on the upper part of the fuselage which is thus slung on the pivot. A bolt runs vertically through the center of the pivot beneath the rocker, on which the entire machine can swing round to the wind, the movement being very free owing to the ball bearings on the crossway piece below. The ailerons attached at either end of the two 12-foot spars are braced up by means of wire stays to the fuselage and a mast is situated at the rear of the machine. They are also supported above by a rubber spring attached to two small masts."

Gas-Engine Waste-Heat to Turbine

IN a recent number of *Power*, E. D. Dreyfus discussed fully the economy obtainable from the use of low-pressure turbines with gas-engine installations where the waste heat in jacket water and exhaust gases is utilized in the turbine. The general lay-out of a waste-heat power installation is shown in plan and sectional elevation, with two horizontal tandem gas-engines and one low-pressure turbine and generator, gas-producer installation, cast-iron exhaust heaters, low-temperature boiler and storage tank. In the heat recuperation, large tanks being essential, working temperature and pressure should be maintained above atmosphere to avoid tendency to collapse under vacuum and to prevent air leakage. The best temperature-range seems at present to be about 64 deg. F., or from about forty-five pounds absolute pressure (274 degrees) to 15 pounds absolute. Curves on this basis of temperature drop are worked out to show the amount of water necessary to absorb this heat under the various conditions of load and period found in working. The area of the surface of the water, or disengagement of the steam may be determined by employing a disengaging velocity of the steam of from 1½ to 5 feet per second. Radiation loss from the heat-storage system is extremely low; 556 square feet of exposed surface would represent a loss of 1 kilowatt per hour. In a case of a 2,000-kilowatt plant, a tank 15 feet in height and 28 feet in length would be required, providing 20 per cent steam space and the radiation loss would be 4.5 kilowatts per hour. The use of the waste heat for heating operations is, however, restricted, because where the ratio of heating requirements to the power demanded in isolated industries or buildings is large, the non-condensing steam motor is superior to the gas engine.

Meteorology and Agriculture

THE programme of the International Institute of Agriculture held at Rome on the 20th of May included some interesting points.. One of these was a proposition made by the French delegate, M. Louis Dop, who is vice-president of the Institute, upon the international organizing of meteorology as applied to agriculture. This question has been already accepted unanimously by the representatives of the forty-eight States which go to form this body. Another point relates to drawing up agricultural statistics. It is also proposed to systematize the figures relating to commerce, production, imports and exports and to freight in transportation for the regular service of the institute. Another question concerns the establishing of figures for the world's prices. The price figures for various products are to be set against the world's production figures so that it will be easy to see the relation which exists at any given time between these two factors.

Sympathetic Ink (yellow).—(a) Write with chloride of antimony; bring out with decoction of gall-nuts. (*b*) Write with sugar of lead, bring out with hydriodic acid. (c) Write with very dilute solution of chloride of copper; visible when heated, disappears when cold.

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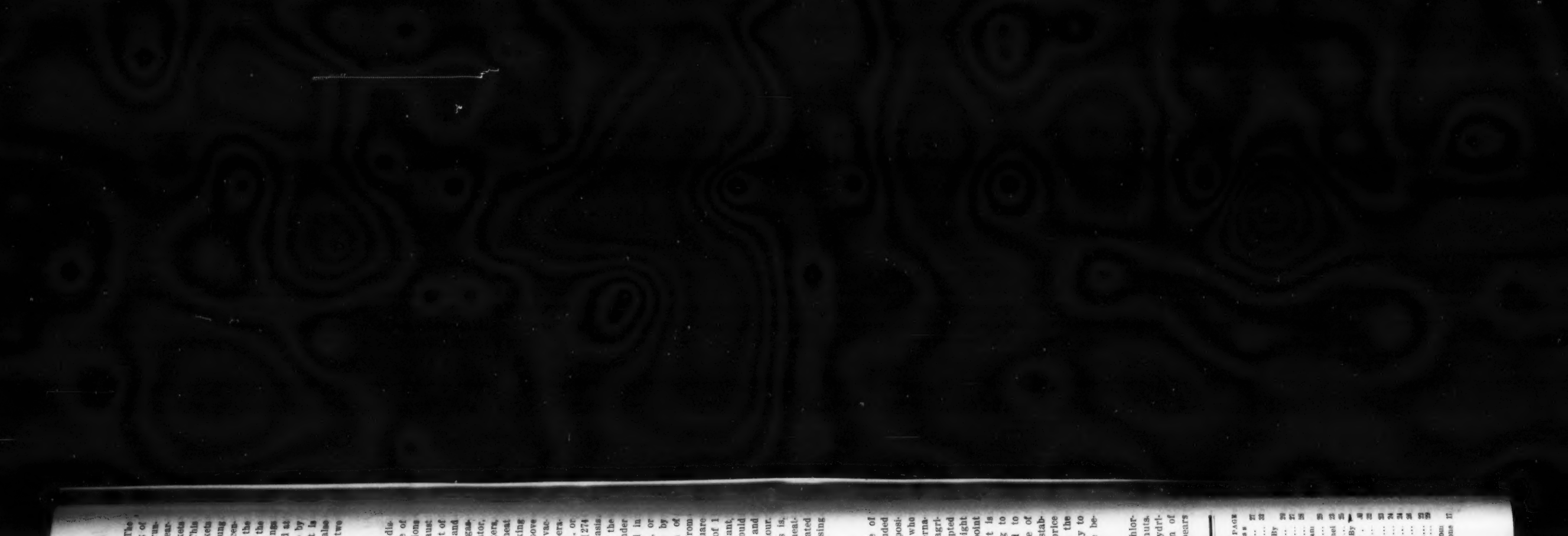
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